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Vol. VII

January to December, 1902

# JOURNAL

OF THE

# WESTERN SOCIETY

OF

# ENGINEERS

PAPERS, DISCUSSIONS, ABSTRACTS, PROCEEDINGS

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Journal of the
Western Society of Engineers.

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## CXXXVII.

### ADDRESS OF MR. O. CHANUTE, THE RETIRING PRESIDENT.

*January 7, 1902.*

Our greatly esteemed honorary member, Mr. L. P. Morehouse, he who was our worthy secretary for eighteen and one-half years, and well governed the infancy and youth of this Society, told us in the delightful talk which he gave us two years ago, something about the modest beginnings of this association; how, on the 25th of May, 1869, twelve civil engineers, the most eminent then in this section, held a meeting to organize the "Civil Engineers Club of the North-West," and were soon joined by ten or twelve others; how professional papers were very scarce; and how it sometimes required the imbibing of "Dutch courage" to go to a meeting.

Now that the society is fairly on its feet,—as old men are prone chiefly to consider the past,—I have thought that perhaps the time has come to glance briefly over the progressive changes which we have made, our difficulties, our successes, and possibly our mistakes; so that, guided by past experience, you may judge what it is advisable to do to make this society still more useful to its members. There are, including myself, but seven of the "sixty-niners" left upon our rolls, and it cannot now be many years before we shall all be further promoted to that grade which is enumerated quite at the end of the list.

There have been three important turning points in the history of this Society, and the turn fortunately took the right direction on each occasion. The first was in making the change from a club to an organized society; the second in entering into an association with three other engineering societies to publish a journal; and the third in the setting up of an independent journal of its own.

During the twelve years of the Club's existence it held 107 meetings and had 92 original papers, having gradually grown to include about 130 members. Mr. Morehouse has told us how, in the early days, it repeatedly occurred that there was no stated meeting for want of a quorum. He has not told us how many constituted a quorum, whether two or three gathered together, and this cannot be ascertained from the by-laws, for there were no by-laws in those days; but we have counted those stated meetings all the same, and have now arrived at our 461st. Some of them, doubtless, were held, for I find in reading the minutes that sometimes collations were provided, as was then done by the American Society of Civil Engineers; but engineers were then, as now, very busy men, and it was very gradually that attendance and papers increased, although there never was any lack of public spirit and hopeful enthusiasm for the profession.

Mr. Morehouse has told us how the meeting set for October 11, 1871, was not held, because of the great Chicago fire, which occurred on that very night; yet the minutes of proceedings show that on the evening of November 20, 1871, a meeting took place at the "New Sherman House," at which the President, Mr. Charles Paine, stated that the library of the Club, consisting of several numbers of the transactions of the American Society of Civil Engineers, had been unfortunely destroyed by the fire. A resolution of thanks to that society was passed, however, for the papers, and they were eventually given to us a second time, thus reconstituting the beginning of our library. At the same meeting an article was also proposed in amendment to the constitution, providing for a grade of "associate members," who were expected to contribute no initiation fees, nor dues, nor papers, and to have no votes, but who might take part in meetings and discussions; a grade of membership in which we are very deficient, as will be stated hereafter.

Colonel R. B. Mason was our first president, and could serve us but one year, for at its seventh meeting the Club had to pass a resolution congratulating him "upon his election to the honorable office of mayor of this city," a resolution which was duplicated on the 3d of April, 1889, upon the election of past President De Witt C. Cregier as mayor. We all know how history has a habit of repeating itself.

Mr. Paine was our second president, and served us three years. He was succeeded by Mr. E. S. Chesbrough, who has left such enduring fame, and who served, in two terms, an aggregate of six years. In those days professional papers were good, but they were scarce, although they always received an elaborate vote of thanks, a practice which was not given up until 1874; and in his annual address of June 8, 1874 (the society year then ended in the summer), Mr. Chesbrough used the opportunity to give the members a good lecture concerning their delinquencies in failing to attend meetings or to prepare papers; a precedent which has since been followed by many of our retiring presidents, but which fortunately need not be conformed to on this occasion. The fact is, that the Club was then doing very well. Ten papers had been provided that year, one for each meeting. With 71 members on the rolls the revenue had been $160, and the expenditures $63.02, so that the Club was even then living within its income. In 1875 the plan was tried of appointing committees to select topics in advance for discussion at meetings, but this proved a failure. After awhile papers became more abundant, and members always had what has been termed their "discuss" with them, so that arrangements were made first with the *Railroad Gazette*, then with *Engineering News*, and then with the *American Engineer*, of this city, to print the papers and proceedings in their columns, and to furnish separate reprints to the Club. Under these arrangements, five thin volumes of papers and proceedings were issued; the first in August, 1876.

In 1880 the Club gave a grand banquet to Count De Lesseps and his suite, this being probably the first occasion on which the association attracted public attention. It gradually increased from a membership of 86 in 1876 to 139 in 1879, and felt that it would be safe to organize into a society. The name was accordingly changed in June, 1880, to "The Western Society of Engineers," and this was incorporated the 1st of September, 1880. There were at that time two sets of opinions: one was to run the society as a local association, and the other was to endeavor to recruit most of the engineers in what was then still the West. Some proposals were made looking in the latter direction, but they came to naught.* In fact, the society did not immediately grow, the membership having actually fallen off from 139 in 1878–9, to 127 by December 31, 1880.

A committee had been appointed October 5, 1880, to report upon a device for a seal. This committee reported progress in 1881, then it took time, and then it asked for more time, but it finally reported May 16, 1882, the present design, which has been admired, by some!

Was it with a view of perpetuating that seal that our excellent member, Mr. Liljencrantz, was appointed chairman of a committee in March, 1881, and reported May 2, 1882, the worthy plan of offering an annual prize for the best paper presented? The committee, however, had also recommended that the prize should consist of a gold medal, that it should be the size of a twenty dollar gold piece, that it should have the seal of the society on one side, and the name of the recipient on the other, and it estimated the cost of the dies at $200. But, inasmuch as that year the income was $978.30, and the expenditures $832.04, the board of directors hesitated; it considered the report at several meetings and finally ordered it (January, 1883,) to be placed on file. But good projects do turn up in time. The present board has seen its way to awarding four medals for the best papers this year. These medals are of modest but enduring bronze. Arrangements will be made to continue the practice. In time some medals may be of silver, and it is hoped that some of the members here present will write papers of such excellence as to move the board to make the medals of gold.

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*As witness many proposals and resolutions. One of the latter passed September 21, 1880, was intended to inaugurate a building fund. Contributions were to be solicited, and they were so confidently expected that it was provided that as fast as they accumulated to $100 this sum should be invested in United States bonds, until it became practicable to select a site and to erect an engineers' building. This came up in a different shape September 2, 1881, but it also proved premature.

Our second important step was taken in 1881. In January of that year it was proposed to enter into an association with three other engineers' societies, to issue joint publications. The plan met with some opposition and was not at first adopted, but finally at the April meeting it was voted (by 29 ayes and 21 nays) to join such an association, and the first issue of the "Journal of the Association of Engineering Societies" came out in November, 1881 The first volume contains 430 pages, but out of an aggregate of 74 papers there were only 7 originating in this Society. To be sure, it was partly our fault that we did not make a better comparative showing, but it created dissatisfaction. It was proposed in May, 1883, to withdraw. This was voted down (25 nays, 21 ayes) and in December, standing committees were appointed to procure the writing of papers and their discussion. This proved a failure, for the second volume of the Journal (348 pages) contained only 7 papers read before this Society out of 51 published. After much discussion, it was voted March 4, 1884 (37 ayes, 26 nays) to withdraw from the association. Letters from other societies and discussions among ourselves so far changed the views of our members that on December 16, 1884, it was voted to continue in the association. The question then remained settled 10 years, but August 4, 1894, a special committee reported that the Society was not getting value for its expenditures and that it would be cheaper to publish independently. Notice of withdrawal was given September 25, 1894; upon appeal to letter ballot this was not sustained (137 nays, 70 ayes) but finally it was voted September 24, 1895, to withdraw (by 179 ayes to 87 nays). A plan was elaborated by the publication committee for printing the transactions and advance copies of papers, and the first number of our present JOURNAL was issued in January, 1896.

I have gone over this bit of history perhaps at tedious length, and this is a good time to acknowledge that I was opposed to the change and that I was quite wrong. I feared from past experience that when the first enthusiasm wore off we should be unable to fill a sufficiently creditable journal to warrant us in asking for exchanges. In point of fact, to the gratification of us all, our members have been greatly stimulated to furnish papers, and we should now pay our tribute of gratitude to their authors and to the publication committees, more particularly those headed by Mr. Reynolds and Mr. Condron. During the 14 years that we continued in the Journal of Associated Societies it published 759 papers, of which 137 were read before our Society, while our own JOURNAL in 6 years has published 157 original papers, many of them excellent, occupying with their discussions, 3,133 pages. It has issued an aggregate of 4,954 pages, we have 195 Exchanges, and the time has come when we may fairly consider publishing the JOURNAL *monthly*, instead of bi-monthly.

It is gratifying to know that the Association of Engineering Societies, which felt pretty blue when we withdrew, has also prospered. It now consists of 11 societies, containing a membership of nearly 2,000, and publishes a good Journal.

The year 1885 was a bad year for the Society. In 1884, with 135 members, the income had been $1,048.00 and the expenditures $1,568.35. In 1885 the revenue fell to $869.80, and $838.96 was spent, and but 106 copies of the JOURNAL were required to supply those members who had paid their dues. Various devices were tried to increase the papers and the attendance. A "question box" was set up in the rooms, the meetings were cut down to twelve a year, and collations made their re-appearance. We already had 11 standing committees, and we increased them to 15. A list of subjects was issued and blank applications for membership were placed in the hands of members, and finally a committee was appointed to revise the constitution; that one device which has been so much chaffed in engineering societies. Upon a report of the trustees on the condition of the Society, it was voted March 2, 1886, to abolish the entrance fee and to reduce the annual dues to $6 for resident and $5 for non-residents. This experiment proved a failure; new members did not come in, and March 6, 1888, the entrance fee was made $5, with yearly dues of $7.50 for non-resident and $8.50 for resident members. Subsequently, (April 3, 1889) the latter were raised to $10 a year.

On June 5, 1889, an amendment to the constitution (originally proposed by Mr. Cregier July 1, 1884) was unanimously adopted: that "Any member who has been a member for 20 years, or upon payment of $100, may become a life member in such manner as provided by the by-laws;" which latter provided for action by the Board of Directors. A number thus became life members. Later on it was seen that this feature threatened to become onerous, and it was abolished by the constitution adopted in 1896; but to preserve good faith there are now ten old members whose dues are yearly remitted by the Board of Directors.

I had thought that it might be interesting to trace the successive changes in the constitution and by-laws and I read all the records of proceedings in our 32 years, (some of them mighty dry reading), wherein I got quite bewildered and lost, so that the task must be left to such of my successors as may deem it worth doing. That unhappy constitution and those poor by-laws! They got as much overhauling and tinkering as those of the American Society of Civil Engineers, and for the same reason. The fact is that a growing society finds changing circumstances and must meet them by corresponding changes in its organic law. There doubtless will be more changes to make hereafter.*

But the one device which seems to have proved most stimulating was the issue of a circular letter by our secretary, Mr. Morehouse, March 20, 1886, pointing out the advantages in joining the Society and inviting accessions. This was followed by many applications and the admission of 70 members during that year. It is suggested that a similar method might be attempted to increase the number of our associates. We now have but 28, while there are several thousand persons in this city who are much interested in the advancement of engineering knowledge.

From the depression of 1885–6 and 7, the Society emerged about 1889, and the ensuing four or five years constituted a period of great activity and growth. Questions were taken up which interested the public and attention was excited. These questions are doubtless fresh in the minds of the members, and will be mentioned but briefly: The first was the Drainage Problem, as affecting also the Chicago water supply. It had been considered at a special meeting, March 9th, 1880, and was taken up again in September, 1889. Many discussions ensued during the next three months, and the mere mention of the names of some of our past presidents, Williams, Cooley, Randolph and Johnston, will bring the debates within recollection. The next quasi-public question to come up, was the so-called Chicago Railway problem in April, 1890. A committee was appointed, headed by Past President Wallace, and brought in two reports; one simply enumerating the various plans suggested, and the other proposing specific action for abating grade crossings. Discussion showed the need of more data, and a new committee was appointed June 4th, 1890. This enlisted the cooperation of the railroads, and it handed in a report May 11th, 1892, which took up both the harbor and railroad questions. It occupies 53 pages of the JOURNAL, including two minority reports, and there was further discussion by members. How far this has influenced the plans now being carried out for eliminating grade crossings there is no way of finding out.

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*The by-laws nearly escaped once. On the 18th of September, 1883, an amendment concerning associates was adopted by a unanimous vote, but it being discovered that no quorum was present, the president declared the vote to be void. It was, however, legally adopted October 16th, but has been abrogated since.

It was in June, 1890, that our past president, Mr. Corthell, advanced the proposal for holding an International Engineering Congress in this city during the exposition of 1893. It will be remembered how this project grew, how it enlisted the co-operation of all the engineering societies of the United States and Canada, how engineering headquarters were established, and the congress became a success.

In April, 1891, Mr. Corthell brought up the subject of "An Enlarged Water Way Between the Great Lakes and the Atlantic Seaboard," and showed the economies which were promised by various projects. This proved the instigating cause of a wide spread movement. The subject was discussed in other engineering societies. An international convention met in Toronto in 1894, and in Cleveland in 1895. An international deep water commission reported in 1897, and a board of United States engineers, of which Past President Noble is a member, has quite recently reported.

The query has sometimes been raised as to how much the prestige and the prosperity of our Society were increased by taking up these live questions. Our experience has been, that this policy has added materially to our notability and membership, but that it has been followed by reactions. The society grew from 183 members in 1886 to 351 in 1890; to 401 in 1892; and to 430 members in 1893, but some of them did not stick. Many will remember the commercial depression in the latter year, and the special meeting March 15, 1893, to consider the financial condition of the Society. Many members who had been carried on our rolls dropped out, and in 1894 our membership fell to 338. It has since gradually increased until we now number 558.

Queries have also been raised as to the propriety of promoting public or local questions, of appointing committees to report on them, and how far such committees should go in reporting on subjects which may have to be submitted to experts. Our experience has been that such questions should be taken up with great caution, particularly those which involve possible legislation; that there is a growing reluctance to appoint committees of investigation, and that it is best that their reports should be confined to the presentation of data, or to the exposition of general principles, leaving the specific application where it belongs, in the hands of those in authority.*

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*One amusing instance will be remembered in which a certain committee on bridge legislation, after compiling at considerable length the legislation in various countries, made some crude suggestions of its own, and had a vast quantity of fun poked at it by one of our members.

The other quasi-public questions which have occupied some of our attention need but bare mention; such as the status of civil engineers in our national public works; the proposed topographical and cadastral survey of Illinois; the bill for the appointment of deputy state engineers; the request of the commissioner of public works that we should make an impartial examination of the water tunnels; and last, but not least, the promotion of schools for technical education and research. This has been discussed on several occasions, we have been addressed by distinguished men who were not members of our Society, the seed has already borne fruit in the Armour and in the Lewis Institutes, and there are indications that greater fruit will be reaped in the future.

The class of professional papers which has always found most favor before engineering societies is that dealing with accomplished facts, such as complete descriptions of important works accomplished and of the methods used. This is sound policy. We have had several of these, besides other papers, during the past year. We have also been favored with five or six addresses by non-members, men who were experts, or who could elucidate subjects new to us or who had done novel things. It is believed that a judicious continuance of this last feature may add interest to some of our meetings.

Each change in our constitution and by-laws has raised the standard of membership, and there is an inclination year by year to apply the rules more strictly. The argument will no longer hold, which was set forth years ago when a certain scheme for chapters was up, that anybody could get in. We have twice been invited to discuss plans for a National Affiliation of Engineers, once by the American Society of Civil Engineers in 1886, and once by the Association of Engineering Societies in 1887. We have always favored such proposals, but no adequate basis has yet been evolved. There will always be necessity for local association and management, and it may be long before a proper plan is proposed.

Our library, after being catalogued and re-catalogued, is now in useful condition and is being extensively used. It contains some 4,000 books and is overflowing the space allotted. Two alternatives may be considered; the first to let it encroach upon our meeting room, with the possible result that we shall eventually be crowded out of it, and the second an arrangement which has been suggested to place in another library of greater scope and resources such valuable books as are very seldom consulted, thus leaving our own as a purely working library. We must, however, continue our efforts to accumulate old books and pamphlets by donation. We will rescue thereby much of the fast-fading history of our Public Works and Railroads.

Very little need be said as to our future policy. The need of more associates has already been alluded to, but we also want many more mechanical, electrical, metallurgical, chemical and mining engineers as active members. We have too few and need more, not so much to contribute to our revenue, as to represent more fully the expanse of modern engineering and to extend the usefulness of the Society.

If we are to award prizes for papers, it may be well to publish annually lists of subjects preferred, as is done by the British Institution of Civil Engineers. It is best to select live subjects, and if we take up local or public questions it will be wise to do so cautiously. When committees are appointed, their reports should be submitted to the Board of Directors before being laid before the members.

In order to give the non-resident members a greater share in the management of the Society, it may be well to have a third vice-president, and some additional directors, and it has also been suggested that the last three or four past presidents should be ex-officio members of the board, in order to preserve some sort of continuity in the management.

It may be remembered that when it was proposed to change our name to that of the "Chicago Society of Civil Engineers" some years ago, the concensus of opinion was that our present name indicated a broader purpose; that the Society should include all kinds and classes of engineering, both civil and military, in the middle west at least. This is a worthy object, and in coming now to the end of my term of office, and in thanking you for the honor conferred upon me, I wish to express the fervent hope that the Society will be so managed in the future that the above purpose may be realized.

## CXXXVIII.

# A PROPOSED DAM AND WATER POWER ON THE MISSISSIPPI RIVER AT KEOKUK, IOWA.

Lyman E. Cooley, M. W. S. E.

*Presented Dec. 4, 1901.*

I have written a very full professional report on the Development of the Water Power of the Des Moines Rapids of the Mississippi River, near Keokuk, Iowa, and Hamilton, Ill., a few copies of which I brought along for such members as are specially interested in the subject. What I will say this evening is not premeditated. I will run over the subject matter in a general way, so as to give you an idea of what is proposed. This report has stirred up the communities immediately concerned, and has attracted considerable outside attention, which I did not expect. I suppose this is occasioned by so bold a proposition as damming a river like the Mississippi, which has an extreme flood volume greater than the St. Lawrence, and nearly twenty times its low water volume, and a range between low and high water of about twenty feet at the foot of the Rapids, and which is practically a mile wide at the point where it is proposed to develop this water power.

There have been schemes at various times for producing a water power on the Des Moines Rapids, but the situation is very different from that of the Rock Island Rapids, and does not readily yield to partial development.

The citizens of Keokuk and the neighboring towns organized a promotion company for the purpose of seeing, first, if a commercial project could be produced; and second, to interest capital. They secured from Congress a bill granting the right to build a wing-dam in the Mississippi River, to construct a canal along the east bank, in Hancock County, Ill., and to produce and maintain power therefrom. The plans were to be approved by the Secretary of War. The canal was not to extend into the bed of the river beyond a certain distance, and was not to interfere with navigation, etc.

Having reached this stage, they employed the speaker and gave him instructions to look over the whole subject matter and see if it was feasible to develop water power, and if so, at what cost, and whether the same would be commercially justified. Knowing something about the Mississippi River, having been on western rivers for several years, I had some forebodings in regard to the project. I visited Keokuk before consenting to undertake the consideration. After looking into the matter, I concluded it was feasible to work out the scheme, and I fixed the time and fee accordingly. A man is not always able to tell at the outset just where he will come out. After working several weeks a change of base was necessary, and the scheme worked out eventually, and recommended, was something quite different from what had been planned at the start. All this cost much more time than I was paid for, but the result was much better than I had anticipated. The promoters are about to seek further legislation, with a view to the largest possible development.

The Rapids proper lie in a rock gorge cut in the Keokuk limestone, about seven-eighths of a mile wide between bluffs, and twelve miles in length between Montrose and Keokuk. In this distance there is a descent of about twenty-four (24) feet at low water. The descent is several feet less (about two-thirds) at high water. The erosive forces have been so uniform that the bed is quite level from shore to shore.

The rock-bound gorge is carved in the limestone to a depth of 70 to 150 feet. The river itself is three-fourths of a mile wide. Below Nashville the slope is broken at low water by "chains" of more resisting rock. Some of these "chains" in the earlier days were cut through to facilitate navigation.

The United States Navigation Canal is along the west, or Iowa shore, about seven and one-half (7½) miles from Keokuk to Nashville, some four and one-half (4½) miles below the head of the Rapids. The upper Rapids are comparatively low in their declivity—four to five feet—while the large fall of some twenty feet is opposite the Canal. In view of the Federal Canal, the proposition for a water power canal naturally takes the east side of the river. The canal must be constructed or built in the bed of the river. The east side is not so favorable. The rock does not lie so well either at the head or foot. At the lower end opposite the end of the Government Canal the rock is some four or five feet higher than on the Keokuk side. Floods drown out the lower part of the Rapids. The most effective part is the middle rapids below Nashville. The government permit contemplated a wing-dam scheme, and it became necessary to select the most judicious points for beginning and terminating the canal. The head of the canal is fixed by the conditions at Sonora Point, one-half mile below the Government Canal, and the lower end by the mouth of Cheney Creek and the location of the shore bar. The canal is thus limited to a length of about six miles, including the basin at the lower end. (Reference to the map will explain this more clearly—Plate I.)

All the conditions indicated about 10,000 effective horse-power as the normal limit of the wing-dam scheme. To extend the canal either down or up stream would so increase the capital in proportion to results as to put it outside of the pale of reasonable expenditure. The canal banks must reach to the extreme high water of the river at the head of the canal. It will be seen, therefore, that a dam does not greatly increase the cost of the canal. As a matter of fact, by raising the banks of this canal four feet and constructing a dam across the river, the horse-power may be increased from 10,000 to 43,000 and add only 15 per cent to the cost. It was thought that when the demand for power had reached the limit of the wing-dam stage of development, that the dam would then be justified, and that still later the horse-power might be increased to 50,000 by digging a tail race from the basin at the lower part of the Rapids.

In order to develop a progressive project it was necessary first to design the dam for actual water conditions. This determines the height of the canal banks and how to make the prism. The length of the dam which it is feasible to produce and the effects of back-water are most important in this determination, and it becomes necessary to know flood volumes and other conditions of flow. The investigation of flow conditions was turned over to Mr. James A. Seddon, a member of this Society, to determine from other points on the Mississippi River, as at Hannibal, Burlington, etc., where there were observations in regard to the discharge, the proper equivalent for Nashville and Keokuk. In addition to this the record was compiled and reduced for twenty years—1881-1900—so as to give a physical history of the stream for this period, such period being assumed to cover the substantial range of phenomena.

The problem of back-water is one of the most obscure in hydraulics. It is enough to say that for variable flow in irregular channels the ordinary determinations are in excess.

A study was made of the effect of dams at different heights in respect to back-water, the contours adjacent to the dam and canal and the United States canal. It developed that a dam ten feet high above low water could be built at Nashville that would produce comparatively little injury. It would raise the water in extreme flood 2.1 feet at the head of the Rapids at Montrose, but the effect practically disappears before reaching Burlington at some point near Dallas; but as the Valley is restricted below Ft. Madison, the number of acres to be affected is not large—some 550 above present flood limits. That level seemed to conform also to the level of the shores along which it was proposed to construct the canal. The extreme high water at the site is twelve feet, so the dam could not well be lower and give free discharge. Under these circumstances the effect of back-water on the flow over a dam is nominal when less than one-third depth over dam. With the dam 6,000 feet long the extreme depth on the crest is taken at 6.7 feet.

High water is raised about 4.7 feet and the low water about 10 feet, and these levels were adopted.

Consideration was also given to the form of dam crest that would give the maximum discharge, but the experimental data is not sufficient for a final type. The coefficient used was determined for a rounded crest by the Cornell University hydraulic laboratory. In a case of this kind it is important to hold the low water level as high as possible without increasing the high water more than is absolutely necessary. The prism of the canal was designed so as to conform to the elevations fixed by the dam. In the twenty year period there were only nine days in which the gauge record showed an elevation corresponding to a less volume passed over the rapids than 20,000 cubic feet per second. That was adopted as standard low water. The canal was designed to carry this 20,000 cubic feet per second with a slope of about 0.8 feet under normal conditions, giving a canal of 7,000 feet of cross-section, and a depth of 20 feet below crest of dam. Under high water conditions it must carry much more water, as the head is much less on account of the relatively greater rise of the water at Keokuk. In an extreme case it may be 20 feet for some 6 feet on the dam. The volume at high water to produce the horse-power would be much larger, but the canal will have additional depth and cross-section.

It was necessary to build the river bank of the canal out of the rock excavated from the prism, and it became a matter of economy to proportion the amount of excavation as nearly as it might be to the amount required to construct the guard bank. This river bank consists of a masonry wall forming the sides of the channel, backed with waste excavation. A toe-wall of concrete is constructed in the river, and paving is carried up to the high water limit.

The lower end of the canal expands into a basin about one-third of a mile in width, and across the lower end of this basin a wall is to be carried as a part of the building line. When it should come time to provide the tail-race, it was to be 400 feet wide and carried down to the bridge, requiring a considerable investment.

The flood volume is taken at 372,500 feet per second. The average run-off for 20 years, as figured upon the average gauge curve, is a volume of 62,000 feet per second, which corresponds to about 7½ inches of water running off of the basin of the upper Mississippi River above Keokuk.

It was a problem how to install this wing-dam project where the head was 11 to 13 feet and where the high water rose entirely above the low water level, as carried from the head of the canal, get your speeds and afterwards have that installation adapted to the project when the heads are 17 to 24 feet and later 18 to 27 feet. This bothered a good deal, and bothered the turbine man, too; but it was finally worked out on the basis of a gallery installation. Each unit is to consist of eight horizontal turbines placed on a single shaft, each 43 to 45 inches in diameter. For the wing-dam proposition ten of these units were to be installed, and two of them connected up to one generator by pulleys and belting. Two were sufficient to give an ample power for one 1,500 kilowatt generator. When a dam should be built giving these larger heads, then it would be feasible to take the five generators, each of which has been connected to a pair of units, and direct-connect each of them to a single unit, and place also five additional generators in the same building, and this gallery system can be continued across the end of the basin. These galleries are 40 to 50 feet between centers, the water from the upper level drowning the floor sufficiently to give ample depth for the turbines which are set on this floor. The culverts discharge beneath the dynamo room. It was difficult to work out the low level bays in reference to high water. The high level bays, when the dam should be built, worked out more satisfactorily. This installation in its ultimate development contemplated 34 units, or practically about 71,000 horse-power of installation, for the purpose of utilizing about 50,000 constant horse-power.

In this connection I wish to call your attention to the value of this pond, some twenty-five square miles. Considerable study was given to the load line under actual practice, such as electric lighting, street railway work, factory work and constant power. It was assumed that a load line for so large a plant would take one-third as variable power, one-third used for a limited number of hours per day, and one-third as constant power. With such distribution it was assumed that 50 per cent over-installation would enable a sale of about five-sixths of all the horse-power hours that were available in the 50,000 horse-power; in other words, that you could realize something less than two-thirds of the installation—between 55 and 60 per cent—in actual sale of power. After these figures were made up it was discovered that 60 per cent had been developed in a general market. With the aid of this pond the water can be conserved in such a way as to realize the results of an over-installation of 50 per cent, and the variation in pond level would not exceed about six to eight inches. A stream of constant flow could not all be sold at certain hours. The reservoir increases its use by some 50 per cent in a miscellaneous market. Considering the conditions existing in the vicinity of Keokuk, it is assumed that one-third of this power will be used locally, one-third at a radius of ten miles, and the other third at forty miles. The average of these is taken as the cost of delivering the power. Figuring up all elements at cost, when the scheme is fully developed, gives some $10.00 per horse-power year, taking a horse-power year at 5,000 hours, for the average of the three different stages,—variable power, factory power and constant power. The wing-dam scheme alone, figured up between $20.00 and $25.00. These costs are delivered to consumer directly or to sub-station.

The results for the wing-dam proposition, in competition with the probable cost of steam power to the state of Illinois, made it a doubtful enterprise. However, as soon as a dam is considered in connection with the canal, it became a splendid proposition, and it will pay to develop it commercially when it has found a sale for something like one-third of the horse-power hours available. It does not change the cost per horse-power materially when the tail-race is considered, but adds to the amount of power. So it appeared at once that this progressive development was not really a commercial proposition unless it was to be followed up immediately—not some years in the future—by the construction of the dam. This led to further investigation as to the feasibility of building a dam at the foot of the Rapids, and also as to the feasibility of raising the dam something like three to five feet over the level of the dam designed for the head of the Rapids at Nashville. The development can be made at the foot of the Rapids for considerably less. It was felt, however, that a radical scheme like a dam at the foot of the rapids would not be justified until all other means of developing this power had proved less meritorious. The sentiment of the people of Keokuk and vicinity is to take the matter up on the broadest lines, and to get Congress to grant a permit for a dam at the foot of the Rapids.

I will not go into this subject any further, but shall be glad to answer any questions.

## DISCUSSION.

*Mr. Finley*—I do not see how you are going to dispense with the Government Canal and use your water power for navigation?

*Mr. Cooley*—I would substitute for the whole power scheme, as worked out in this report, a complete dam at the foot of the Rapids something like thirty feet high, clear across from one shore to the other, in lieu of all power canals, and in lieu of the Government Canal, put a lock at one end, and put some short races in the walls at either end of this dam, and so construct this dam as to give sufficient room near the shores to make the power development, in the shape of a "V" up stream to get the necessary length. It is an entirely feasible proposition—extremely bold, but very satisfactory. You can raise the height of the dam and raise the level of the water by several feet—at least three to five feet—and save more on installation than all the damages you can produce in the forty miles of stream. It is economy to build a power that will give you at least a fall of about thirty-four (34) feet at low water, and, of course, something less—about twenty to twenty-two feet—at extreme high water, which has occurred but once in twenty years, and two-thirds of the elevation of extreme high water in the river has prevailed for only 167 days in twenty years, so that these extremes should not be given much weight except in fixing limits.

*Mr. Snow*—I would like to ask if the commercial form or the special form of turbine was considered?

*Mr. Cooley*—In making up the estimate and studying that question for the purpose of the preliminary report, we used the commercial form of turbine. There are several available makes of turbine. The combination unit on a horizontal shaft has proved effective. I did suggest in this report that a special form of turbine might be devised that would fit the conditions better than the commercial, in view of extreme range of head and volume. I do not think it would be necessary or expedient for the high level conditions.

*Mr. W. H. Pearce*—I suppose the design is to build up manufacturing industries in the neighboring towns?

*Mr. Cooley*—Within a radius of about forty miles around Keokuk there are several good towns like Fort Madison, Burlington, Quincy, Hannibal, Galesburg and Monmouth, and there is no reason why they should not be able, with the cheapness of development that is feasible there, to send it as far as Pekin, Peoria or St. Louis, or anywhere within 100 miles. The expectation is to induce people who are hunting for cheap power, to take up this enterprise on the theory that Keokuk is in the center of the corn belt and in the center of the Mississippi Valley, and consequently is as favorable a point for the use of power and for producing a market as any point in the United States.

*Mr. Finley*—Is the price of $10.00 per horse-power the earnings on the investment?

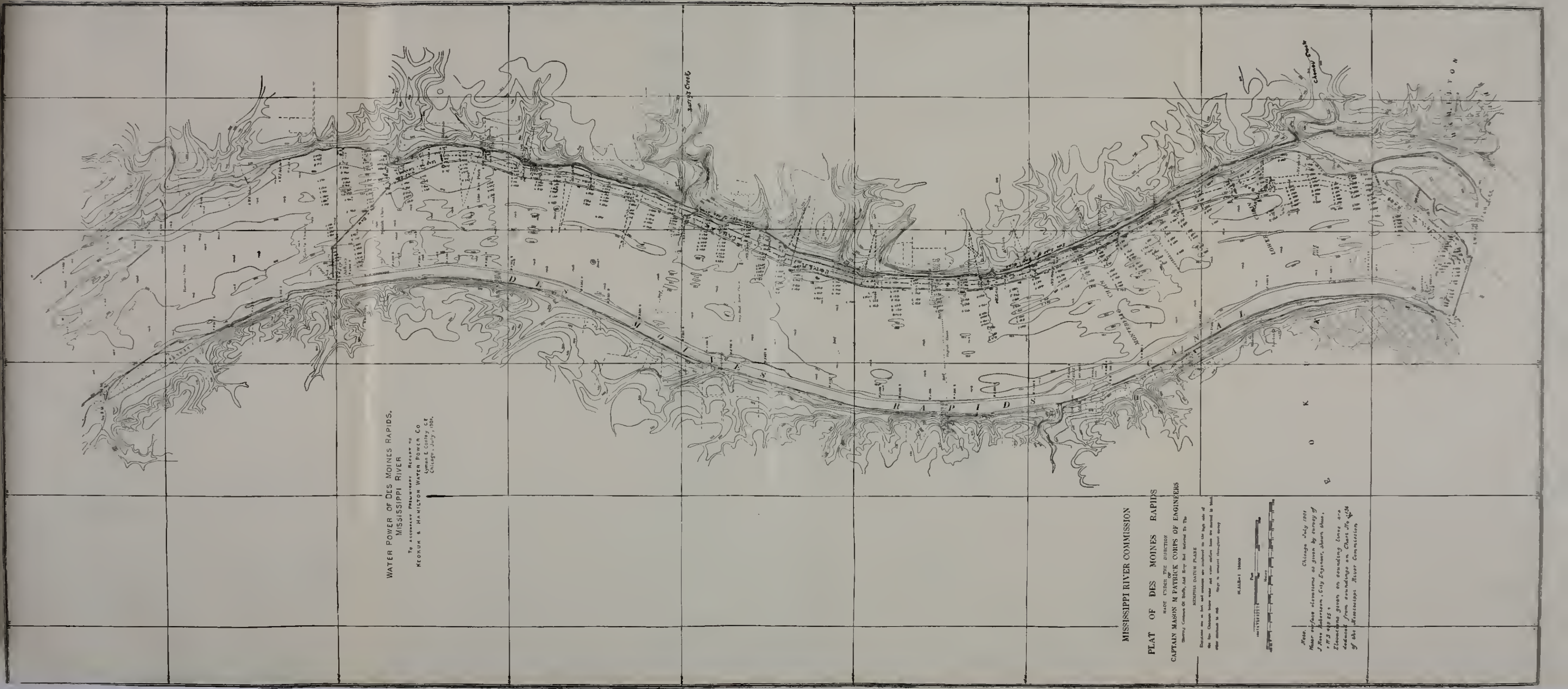
*Mr. Cooley*—On the work they call permanent we figured interest and taxes at 5 per cent, and maintenance at ½ of 1 per cent. I think that work can be maintained for that amount. On the other work, installation, we figured an aggregate amount of 11 to 12 per cent, and in addition to that a fixed charge for service.

*Mr. Finley*—Would the price of $10.00 per horse-power cover those items?

*Mr. Cooley*—Yes. The items are given here (Report) in detail; interest and taxes, repairs, maintenance, renewals and service.

*Mr. Pearce*—Would that be the cost delivered at Galesburg, for instance?

*Mr. Cooley*—The figure I gave is the average for three conditions—one-third local, one-third within a limit of ten miles, and oneried out indefinitely, and from that standpoint I think it should be encouraged. One objection might come from the raftsmen who wish to run rafts down the stream without going through the canal, but that business is now pretty well over, and they would use this


WATER POWER OF DES MOINES RAPIDS.
MISSISSIPPI RIVER
To accompany Preliminary Report to
Keokuk & Hamilton Water Power Co
Lyman E Cooley C.E.
Chicago, July, 1901.
DES MOINES RAPIDS CANAL
KEOKUK
LOWER
MONTROSE
HAMILTON
Cheney Creek
MISSISSIPPI RIVER COMMISSION
PLAT OF DES MOINES RAPIDS
MADE UNDER THE DIRECTION OF
CAPTAIN MASON M PATRICK CORPS OF ENGINEERS
MEMPHIS DATUM PLANE
SCALE 1:10000
Feet
Meters
Note.
Chicago July 1901
Water surface elevations as given by survey of J Ross Robertson, City Engineer, shown thus,
Elevations given on sounding lines are deduced from soundings on Chart No 136 of the Mississippi River Commission

third for a limit of forty miles. In the case of Galesburg it would be somewhat greater. There is a figure given in the report for forty-mile distance. In making a comparison with steam power we used these figures. Some years ago I made some original computations on the subject, but this time I did not go into the matter in detail, using the best judgment and authority I could obtain.

For constant power used for twenty-four hours in the State of Illinois, with the usual price of coal, we figured .6 cents per horse-power hour; for factory conditions, using 3,000 to 3,500 hours a year, .8 cents per horse-power hour; for variable power, such as electric light, trolley work, etc., 1 cent per horse-power hour. Assuming the average of the three conditions gives .8 cents per horse-power hour. If you were delivering that work by steam power in place of water wheels, on the basis of a horse-power year of 5,000 hours, the cost would be $40.00.

*Mr. Finley*—That would give quite a large margin between the cost of water power and steam power?

*Mr. Cooley*—Yes, I give my reasons for that in my report. The chief reason is that water power must show a great saving over steam power, and if you can produce at one-half the cost of steam power, there is something to divide, and something also for a margin to induce people to come and use it.

*Mr. Finley*—At the maxim flood level, how far would it back water up in the Mississippi?

*Mr. Cooley*—As a matter of fact it backs the water at a less distance at flood level than low water, and the effect practically disappears at about twenty-five (25) miles up stream; by raising the flood water something like four feet above normal at the dam site there is quite a steep slope above—the level is raised about two feet only at Montrose, and diminishes up stream quite rapidly.

*Mr. Pearce*—What might be some of the objections on the part of the government to that dam across the river?

*Mr. Cooley*—There ought to be none. It is a scheme that has very great merit from the standpoint of improvement of the river. It costs quite a considerable sum to maintain the United States Canal—something like $40,000 a year.

The property involved would of course only be a fraction of the $4,500,000 involved in the present canal. It gives a very large depth of water in the river for navigation, and greatly improves the stream. The time might come when such a scheme could be carried out indefinitely, and from that standpoint I think it should be encouraged. One objection might come from the raftsmen who wish to run rafts down the stream without going through the canal, but that business is now pretty well over, and they would use this lock in preference, if they had any choice. I do not know that the steamboats make any use of the Rapids now.

*Mr. Finley*—What is the nature of the construction of the dam you would use there?

*Mr. Cooley*—It would be of concrete—first-class concrete.

*Mr. M. K. Trumbull*—Have the borings disclosed many seams in the rock?

*Mr. Cooley*—The rock is more or less jointed. It does not appear to be as badly jointed, however, as the limestone here at Chicago, and it seems to be a very stable stone on which to build a dam; but a very limited head of water will displace solid ledges in a most marvelous way, and a dam cannot be built on rock without proper care and design. I think a rollway can be designed that will be effective. In fact I am certain it can, but it is always a matter for great care.

*Mr. Finley*—Would you favor the idea of a rollway on both sides of the dam?

*Mr. Cooley*—Yes. You cannot tell what kind of tremors will be set up and how they will affect the masonry, and I do not want any jet of water playing upon the sedimentary rocks lying in their beds. I have seen too much of the effects.

*Mr. Finley*—Is there any danger from the depositing of silt around the dam?

*Mr. Cooley*—I think not. There will be, of course, a certain amount of silt deposit in the pool above, but I think you will have a slack water pool for many miles much deeper than the average river. That is the experience along the river where there are conditions that produce a change in slope within certain limits.

*Mr. Finley*—The cost does not seem to be exorbitant for the return in horse-power.

*Mr. Cooley*—It is not, considering the magnitude of the river; you have got to bore with an augur rather than a gimlet, to make it a practicable enterprise. It has to be developed on a large scale. And so it has turned out, after going through all the details, that the boldest scheme is the cheapest and the best.

*Mr. Boardman*—Would you not anticipate considerable difficulty in getting a tight coffer-dam for the construction?

*Mr. Cooley*—Yes, but at the same time there are many months in the year when the water running down is not over two or three feet over these chains. You can practically build that dam across that river all but a few hundred feet, and let the whole river go through it in flood time and watch your opportunity and close it after that. That is probably what you would have to do, and I think there would be no serious trouble about it.

*Mr. Boardman*—I saw them put in that water power at St. Louis and they had to make a coffer-dam to stand probably three or four times the head you would have.

*Mr. Rice*—Would the ice formation be a cause of trouble in a high dam?

*Mr. Cooley*—Ice is a serious problem, and has attracted a good deal of attention. It forms on all rapids and forms down at the lower end of these Rapids. In these long rapids it accumulates and develops to a very high degree. Anchor ice formation seems to be the special function of rapids and its accumulation through a long winter some times produces startling effects. The phenomena is highly developed on the St. Lawrence. It is more or less incidental to all streams until the ice sheet is set. The effect of a dam is to produce a lake or pool condition, and to produce sheet ice and do away largely with anchor ice formation and accumulation. I anticipate little more trouble from this source than in Lake Michigan.

*Mr. Rice*—Is there not danger in the spring time when the ice breaks up?

*Mr. Cooley*—The ice will go over the dam with considerable depth of water, and, of course, ought not to injure the dam. I know of only one case where a dam has really been injured by ice. That was a case where the dam was used for mill power. It had served for forty-eight (48) years without injury, and one winter the water was drawn down and the ice sheet froze to the top or coping. When the water raised it lifted the coping and dropped it below the dam. Large ice sheets break up in passing the crest. There may be possible abrasion at the rollway, but if this becomes serious it must be provided for.

The production of monolithic masonary in combination with metal is a resource adequate to almost any condition that cannot otherwise be avoided.

# CXXXIX.

# A GAS ENGINE DRIVEN DIRECT PRESSURE PUMPING PLANT, WITH SOME EXPERIMENTS ON PUMP VALVE AREA.

D. W. MEAD, M. W. S. E.

*Presented Dec. 4, 1901.*

This pumping plant was installed at Winchester, Indiana, for the Citizens Water and Light Company, who have the franchise for furnishing water and electric light at that place. This plant was of somewhat peculiar design on account of the conditions under which it is operated. Winchester is in the natural gas field of Indiana, and natural gas can be obtained for 12½ cents per thousand cubic feet. At this price gas engines furnish the most economical power which can be obtained at Winchester, and therefore was selected as the active power, both for the pumping plant and for the electric lighting plant, which is installed in the same station.

The company installing the works did not wish to erect a stand-tower, but desired to pump directly into the mains. While the gas engines used can be regulated, by a change in the governor, to operate at different speeds, they cannot be automatically controlled through a sufficient range of speeds, and with sufficient rapidity to permit of the successful operation of the pumps against the varying service. This is due largely to the fact that the minimum supply of water needed, especially when the works were first installed, and also during the hours of night, is so small that the engine cannot be run slowly enough to handle the small amount of water needed. While this could have been overcome by the use of relief valves, or by a bleeder in the mains, such methods would result in an extravagant use of fuel, as the greater proportion of water pumped during such hours would be wasted, and all water whether used or wasted would be pumped against the full head carried in the mains.

To allow the engine to run at a reasonable speed, and to reduce the cost of operation to as low a figure as possible, a by-pass valve was placed between the suction and discharge chambers of each pump, and a check valve was placed on the discharge pipe, so that when the by-pass valve is open, and the water from the discharge passes freely into the suction pipe, the pressure in the mains is retained by the check valve, and the water will circulate through the pump at the expense of only a sufficient amount of energy to overcome the friction of the machines, and the friction of circulation.

To permit the use of this by-pass valve, and at the same time retain a nearly constant pressure on the main, a surge tank, consisting of a heavy steel tank four feet in diameter and fourteen feet in height, was placed in the station and connected with the mains. Under ordinary conditions the tank is supplied with sufficient air so that when the tank is half-full of water the pressure will be that normally carried on the mains (i. e., a pressure of about 45 pounds to the square inch). The surge tank is connected by a small pipe with the by-pass valves of the pumps, and whenever the pressure rises above 45 pounds the by-pass valve opens, and the water circulates or rotates through the pump passage only, the pump ceasing at such times to force water into the mains. While the pump is circulating the water in this manner, the pressure from the surge tank maintains the pressure on the mains, and whenever the pressure on the mains falls below 45 pounds the by-pass valve is automatically closed, and the pump again begins to supply water. The variation in pressure necessary to operate the valve is about two pounds.

The arrangement above outlined is shown in Fig. 1, which shows a section of the pumping pit, and elevations of the gas engine, pump, surge tank and connections. In Fig. 2 is shown the plan of the same.

The water supply at Winchester, Ind., is derived from three 10-inch wells sunk in the lime rock a depth of about three hundred feet. When the wells were first drilled, the water stood about six feet below the surface, but in order to obtain a sufficient capacity from the wells it was found necessary to place the water ends of the pumping machinery in a pit at a depth of about fifteen feet below the ground level, and to connect the wells with the suction pipe at that depth. Fig. 3 shows the general arrangement of the wells.

The wells were finished with 10-inch pipe, driven well into the rock, and thoroughly packed off. At a point about fifteen feet below the surface each well was provided with a Tee connection to the suction pipe. A gate valve separated each well from the suction pipe, and a valve was also placed above the Tee on the drive pipe of the well. When the well was not in use the water rose above the valve in the vertical pipe. The valve was then closed, leaving a water packing, which made the well air-tight, and permitted the water to be drawn through the suction pipe some fifteen feet or more below the Tee connection.

The engines used to operate these pumps are Nash Gas Engines of 40 horse-power each. The pumps were designed and built for this installation by the Gould Company, under the writer's specifications. The plant has been in satisfactory operation a year or more.

In a paper on the "Mechanics of Suction and Suction Pipes," published in the JOURNAL OF THE WESTERN SOCIETY OF ENGINEERS, February, 1899, the writer briefly discussed the friction losses in the passing of water through the valves and water passages of pumps, and gave some results of friction tests made on various pumps.

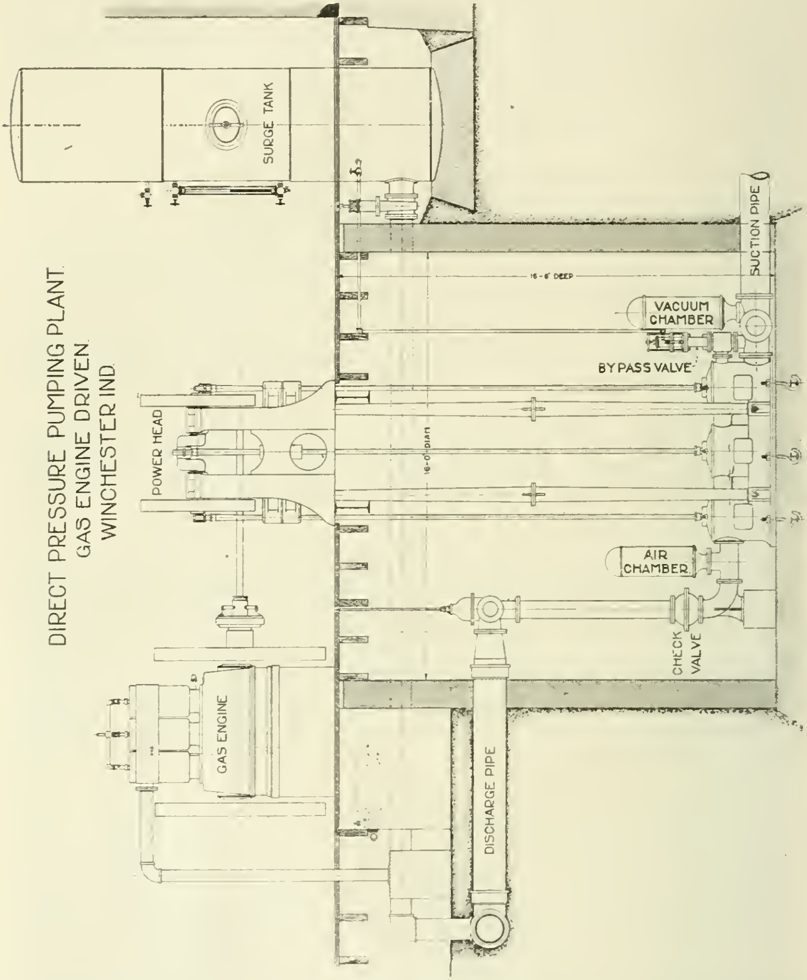
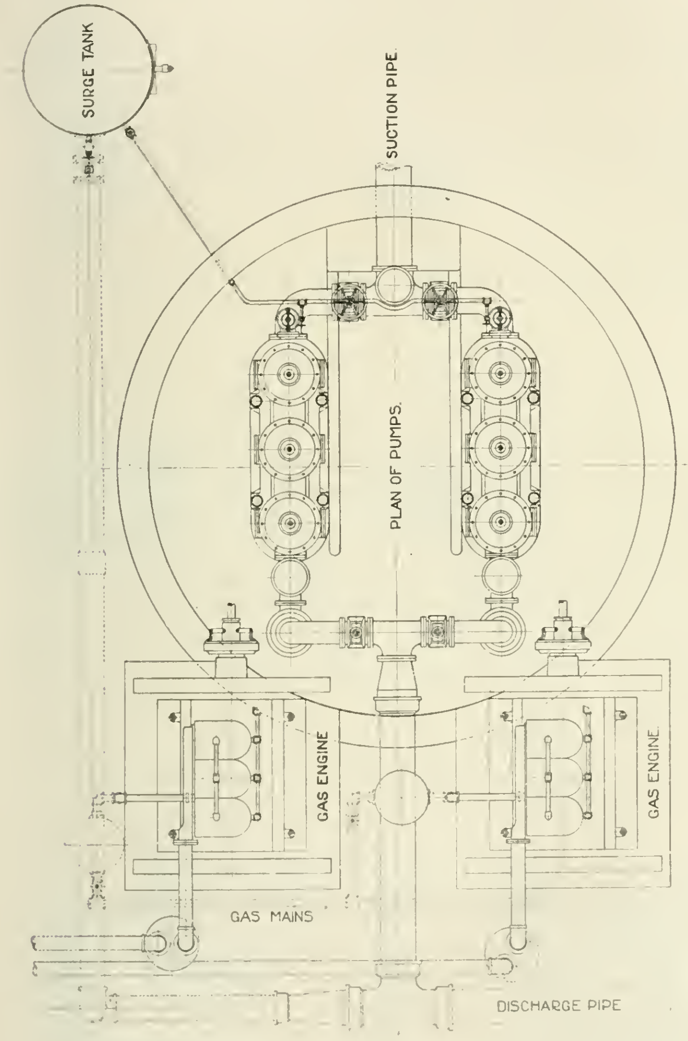


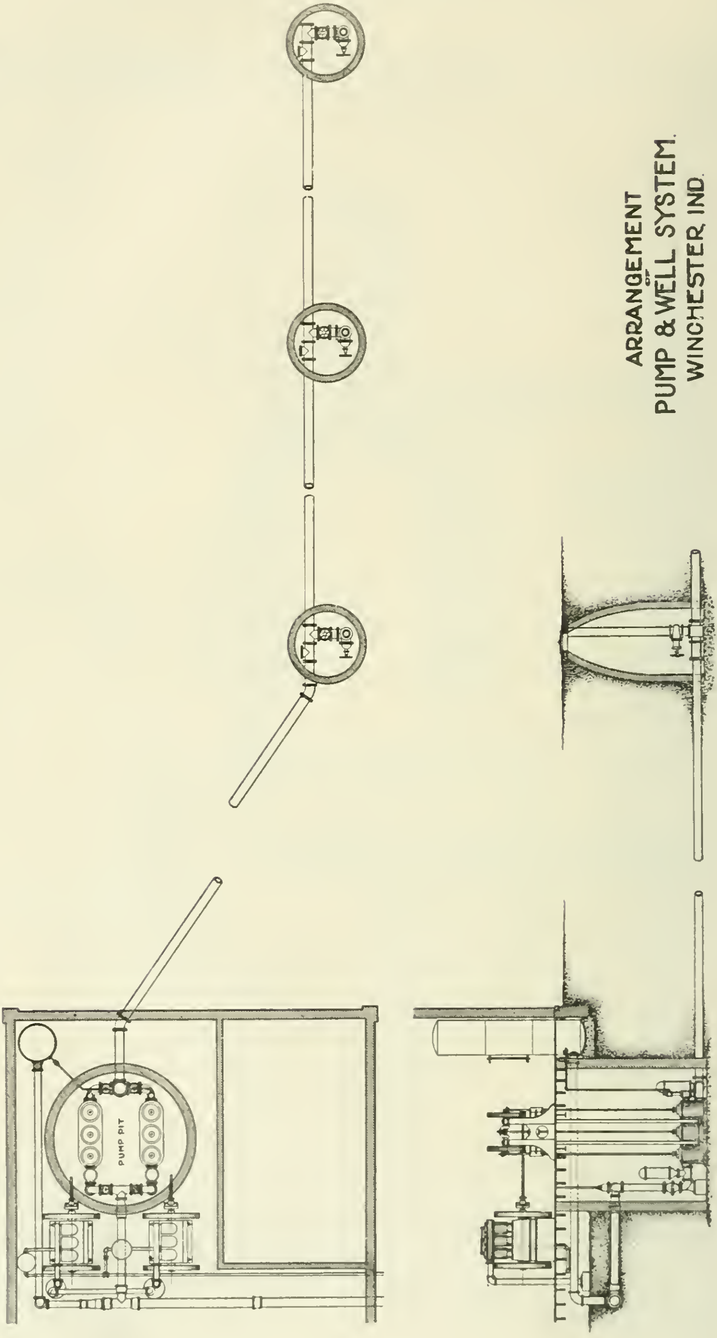
FIG. 1.

It was shown that even in our best pumping engines, a friction loss or 4 to 7 pounds was a common result even in large sized pumping engines. The loss seriously affects the efficiency of pumps, especially on low service, representing, as it does, on a total pressure of 45 pounds, which is a common pressure for water works service, a loss of from 9 to 15 per cent. It is very desirable to ascertain the cause of these losses in order to determine the possibility of reducing them.



DIRECT PRESSURE PUMPING PLANT.
GAS ENGINE DRIVEN
WINCHESTER, IND.

Fig. 2.



ARRANGEMENT OF PUMP & WELL SYSTEM. WINCHESTER IND.

Fig. 3.

An opportunity was afforded in the construction of the pumping plant at Winchester, Ind., to make some observations on the effects of valve areas on the friction loss in those pumps. Restricted valve area was believed to be an important source of loss, but this belief the experiments did not seem to bear out to the extent anticipated. The experiments made to ascertain the influence of valve area were not sufficiently extensive to lead to any general or exact conclusion, but as such experiments are not numerous, the facts determined are believed to be of interest.

The pumps were placed in service during the summer of 1900, and on account of the dry weather, the head of water had fallen in the well so that it was only slightly above the water end of the pump when the experiments were made. These experiments were made by connecting a steam engine indicator to each of the three water cylinders, and by taking cards from each cylinder, both under the normal condition of the valves and with the valves' area restricted.

Fig. 4 shows various sections of the water end, in order to make clear the arrangement of the valves and water passages in the pump.

Illustration A in Fig. 4 shows a cross section through one of the cylinders. In this view the piston is supposed to be descending and the water is being discharged through the discharge valves. On the down stroke the piston is performing the minimum amount of work, which amounts simply to the friction of the piston, and the work of passing the water through the discharge valves. The maximum work is performed on the up stroke, when the connecting rods are in tension. This condition is illustrated in the longitudinal section through one of the cylinders represented in B, Fig. 4.

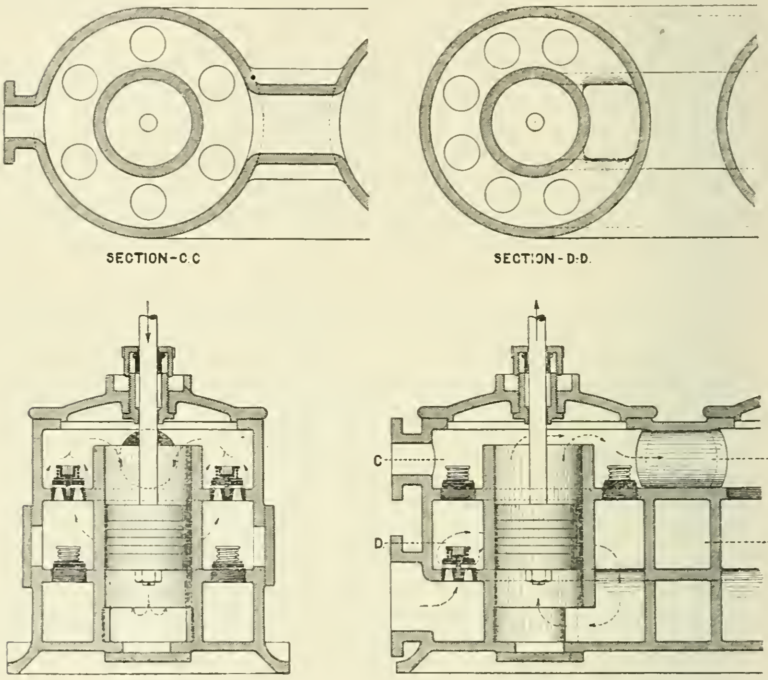
In B it will be noted that as the piston raises, the water is drawn in through the suction valves, and follows behind the piston, while the water in the discharge end is being displaced.

In A, on the down stroke, the water simply rises through the discharge valves, and occupies the place made vacant by the descending piston, no work being done other than that caused by friction.

C, Fig. 4, is a horizontal section just above the suction valves, and shows the arrangement of the six suction values, and the opening connecting the passage above the suction valves with the piston chamber. The pistons of these pumps are 7⅞ inches in diameter, having a cross section of 48.71 square inches, and a stroke of 12 inches.

There are six valves in both the suction and discharge of each cylinder. These valves each have a free waterway of 4½ inches area through the seat. There are six valves in both the suction and discharge of each cylinder; hence the free valve area equals 27 inches, or about 55.4 per cent of the piston area.

In Plate II. are shown to scale the indicator cards from the various pump cylinders. On each card is shown both the atmospheric line and the pressure line due to the water pressure when the pump was not in operation.



SECTION-C.C SECTION-D.D.

FIG. A. FIG. B.

Fig. 4.

The first horizontal series of cards, show cards taken from each cylinder when circulating water at 32 revolutions per minute, and with unobstructed valve area.

The second horizontal series of cards represent the cards taken from each cylinder when circulating water at 44 revolutions per minute, and the third series represent same conditions when circulating water at 51 revolutions per minute.

At the time of taking the circulating cards there was no suction on the wells, as the water in the pump was simply rotated or circulated through the pump, the pump being kept full of water by the well pressure. The portion of the card below the water line, shows therefore, the friction work in the suction valves and passages.

The cards obtained under regular service are shown on the bottom line. In those cards a vacuum of 5 to 6 pounds, or of 11½ to 14 feet is shown. This represents the friction in suction valves and passages, plus the distance the wells are pulled down to furnish the amount of water pumped during the time the cards were taken.

The cards showing the circulation of water are taken with a 10-pound indicator spring, while the cards on regular service are taken with a 40-pound spring. Making allowance, however, for this difference in scale, the difference in areas of these cards represents the saving of power accomplished by this system of pumping during the time the pump is idle over what would be expended if the service was controlled by relief valves.

In the experiments, the south cylinder was next the discharge pipe, and the north cylinder was next the suction pipe and by-pass valve.

It will be noted that the cards from the north cylinder, when the water was being circulated, show that a certain amount of air or gas was reaching this cylinder; hence the determinations from this cylinder was of no value in the experiments.

After the cards shown in Plate I were taken, the south and centre cylinders were opened, and in the south cylinder four of the six valves in both the suction and discharge were blocked so that they could not open thus restricting the valve area in this cylinder to one-third of the original amount.

In the centre cylinder, two suction and two discharge valves were blocked, thus restricting the free valve area to two-thirds of the original amount.

Cards were taken at 30, 44 and 50 revolutions per minute. These are shown in Plate III.

The lower line of cards taken with the 100-pound indicator-spring at 50 revolutions per minute, show the action of the pump under a fire pressure of 100 pounds. An analysis of the results obtained are as follows:

EXPERIMENTS ON FRICTION OF WATER IN WINCHESTER PUMPS.

| | Average velocity of water through valves, feet per sec | Average Pressure Shown by Cards. | | | Probable friction in by-pass valve | Revs. per min |
|---|---|---|---|---|---|---|
| | | Suction pressure. | Discharge pressure. | Total press. | | |
| Experiments with full valve area. | | | | | | |
| Centre Chamber...... | 1.87 | 1.31 | 4.00 | 5.31 | | |
| South Chamber....... | 1.87 | 1.21 | 3.95 | 5.16 | | |
| Average......... | 1.87 | 1.26 | 3.97 | 5.23 | 2.71 | 32 |
| | | | | | | |
| Centre Chamber...... | 2.65 | 1.32 | 6.23 | 7.55 | | |
| South Chamber....... | 2.65 | 1.15 | 6.10 | 7.25 | | |
| Average ......... | 2.65 | 1.23 | 6.16 | 7.40 | 4.94 | 44 |

| | Average velocity of water through valves, feet per sec. | AVERAGE PRESSURE SHOWN BY CARDS. | | | Probable friction in by-pass valve. | Revs. per min. |
|---|---|---|---|---|---|---|
| | | Suction pressure. | Discharge pressure. | Total press. | | |
| Centre Chamber...... | 3.07 | 1.20 | 8.30 | 9.5 | | |
| South Chamber. ..... | 3.07 | 1.22 | 8.57 | 9.79 | | |
| Average... ...... | 3.07 | 1.21 | 8.43 | 9 64 | 7.22 | 51 |
| Experiments with ⅔ valve area. | | | | | | |
| Centre Chamber...... | 2.9 | 1.36 | 3.67 | 5.03 | 2.31 | 32 |
| Centre Chamber.... | 3.97 | 1.37 | 6.13 | 7.50 | 4.76 | 44 |
| Centre Chamber...... | 4.52 | 1.44 | 7.91 | 9.35 | 6.47 | 50 |
| Experiments with ⅓ valve area. | | | | | | |
| South Chamber ...... | 5.8 | 1.70 | 4.36 | 6.06 | 2.66 | 32 |
| South Chamber....... | 7.95 | 2.00 | 6.67 | 8.67 | 4.67 | 44 |
| South Chamber....... | 9.05 | 1.97 | 9.46 | 11 43 | 7.49 | 50 |

Each of the results given above is the average of four or five cards, in which no radical differences were observed.

In the experiments with full, or 55.4 per cent valve area, the friction in the suction valves and passages at the various ratio of flow did not increase, with the velocity as was expected, but instead decreased slightly or remained practically constant.

Assuming the friction in the discharge valves and passages equal to that of the suction valves and passages (although from the arrangement of the discharge it is probably slighter greater), the friction through the by-pass valve was calculated and is shown in the fifth column.

The increase in friction due to the decrease in valve area is much less than expected, being at 36.9 per cent valve area, an increase of only 10 or 12 per cent, and at 18.45 per cent valve area, from 40 to 65 per cent greater than with the valve area 47.5 per cent of the piston area. The difference in the calculated friction of the by-pass valve during the experiments with full valve area and with partial valve area is believed to be due to a difference in the valve opening.

The friction in valves and water passages in these pumps is very low, being apparently 2½ to 3 pounds with full valve area, 3 to 3½ pounds with ⅔ valve area, and possibly 4 to 5 pounds with ⅓ valve area.

The suction passages in these pumps are ample, and the discharge passages are less restricted than usual in this style of pump. The writer is led to believe by these experiments, and others previously made, that ample and uniform water passages and few obstructions and reversals of the water current are more important than large valve area in reducing the friction losses in pumping machinery.

## DISCUSSION.

*Prof. P. M. Chamberlain*—I understand the friction through the relief valve is obtained by taking the difference between the pressure above the atmospheric line and the pressure below. If there was no friction whatever, the piston would move up and down without exerting pressure above or below the atmospheric line, but owing to the friction there is a negative pressure on the suction and a positive pressure on the discharge side, while the varying velocities indicate that the friction in the relief valve is nearly constant.

The friction of the relief valve, calculated from the cards, is about five pounds, if I remember rightly, from which we may infer that the friction of the water through the pump is not much greater with a high velocity than with a low; then the loss is due almost entirely to the reversal of the direction of current.

My discussion is hypothetical, but if the assumptions are correct, the loss is due almost entirely to the reversals of current, and it increases quite rapidly with the higher velocities. I wish the experiment showed a very low velocity, indicating what the friction in this relief valve would be in that case, and whether it was open the full amount each time.

Some arrangement might be made whereby the water could be carried in a continuous direction, or perhaps have air cushions to absorb the inertia and carry it through when the piston has stopped. The greater loss appears, as before pointed out, to be due to the fact of starting it in one direction, and then bringing it to a dead standstill for the moment, and then accelerating the water again from a standstill. All of the water in this circuit starts and stops for each stroke of the pump.

I would like to ask if Mr. Mead thinks that a continuous circuit would reduce the friction of the pump?

*Mr. Mead* When rotating water, the discharge of the pump is cut off by the check valve beyond the air chamber, and the suction connection remains open. For this reason, it will be seen that when the pump is drawing water into the pump chamber, if the water should come more readily from the suction pipe than from the by-pass valve, it will pass into the pump from the suction pipe. The diagram, therefore, shows none of the friction of the by-pass valve below the atmospheric line. On the contrary, the necessary pressure to force the water through the by-pass valve is shown above the atmospheric line on all the cards.

The friction of the by-pass valve is not constant, but in the experiments is shown to vary from about 2½ pounds to 7½ pounds, as the revolutions increase from 32 per minute to 51 per minute.

At any given rate of speed the velocity of the water through the by-pass valve is approximately constant; that is to say, the pump under discussion is a triplex pump, and the pistons are operated by cranks set 120 degrees apart, so that while the water in any given cylinder will start and stop with the piston, the velocity of the water in the discharge chambers, being the resultant of these pistons' velocities, has, therefore, very little variation, and on account of the air chamber the velocity may be regarded as practically constant.

The total loss due to both friction in the valves and the reversal of the current seems to be, from the experiments, about 2.5 pounds with full valve area, 2.8 pounds with ⅔ valve area, and 3.8 pounds with ⅓ valve area; these amounts not varying essentially as the revolutions increase from 32 to 51. The friction is the by-pass valve, however, increases directly as the velocity increases. There can be no question but that there is a small loss due to the stopping and starting of the water column, which might be overcome by a continuous flow pump. It is, I think, comparatively insignificant, however.

*Prof. Kerr*—I think we are indebted to Mr. Mead for the description of his very neat solution of one phase of the water works question, but I wish he could have given us the results of a test of this plant by which the duty could have been accurately determined. A gas engine is so much more efficient than a steam engine that in these small units I think that we may expect to find duties corresponding closely to that of the large pumping plants. I made some calculations on the probable efficiency of this pumping plant and found the efficiency to be about as high as that attained by the best steam pumping plants.

Another question arises in my mind, as to the number of years to elapse before the level of water in the ground sinks below the reach of the pumps as they are installed in this plant. It seems to be a fact that there is a slow subsidence of the water level in artesian wells, due to the increasing demands on the underground supply.

However, it is a matter for congratulation of villages and towns needing a pure public water supply, that so reliable and efficient a pumping plant as that presented is available.

*Mr. Finley*—I would like to ask how the ordinary gasoline engine compares in efficiency with natural gas and with coal.

*Mr. Mead*—The cost is just about double with a gasoline engine, when coal sells at $1.50 to $1.75 per ton, that is, in an ordinary plant of say 25 to 50 horse-power the cost of coal will be about one-half of the cost of gasoline. In comparison of gasoline power with a high grade steam plant of a larger size, the cost of gasoline will be comparatively much greater.

*Mr. Finley*—How would it be with producer gas?

*Mr. Mead* I cannot say off-hand, except in this way. I understand that R. D. Wood & Co. manufacture a gas producer which they will guarantee to produce gas that will give 10,000 heat units per pound of anthracite pea coal. The better class of gas engine makers will guarantee to develop one horse-power on about 12,700 heat units. These figures combined will give an indicated horse-power on a little over a pound and a quarter of coal, whereas the ordinary steam engine will require from 4 to 6 and sometimes 8 pounds of coal per horse-power per hour with the ordinary small steam plant.

*Mr. Finley* I notice in your indicator cards that under 40-pound pressure you have quite a fluctuation at the beginning of the line, which is due, I suppose, to the fluctuation in the spring. Did you take any corresponding indicator cards from your engine?

*Mr. Mead*—No, I did not. As a matter of fact I had my indicator equipped with a 100-pound spring, and ¼-inch piston area, which would give pressure up to 400 pounds. I have used this indicator on a number of gasoline engines, but it was too weak to measure the maximum pressure in this gas engine cylinder, which must have been between 500 and 600 pounds per square inch.

*Prof. A. N. Talbot* This paper describes a very interesting design, which has the merit of being fitted to the requirements of the local conditions. The use of the by-pass valve in connection with a check valve and a pressure storage tank is an interesting detail. This method removes the objection which often holds against power pumps for small stations. However, the data given on the loss through the valves and pump passages, and the variation in loss for changes in valve area, are the really important and valuable feature of the paper, because little information is available on these points.

The diagrams show an excellent arrangement in the design of the pumps, with large water passages and without abrupt turns. The velocity of the plunger (from 1 to 1½ feet per second) and the smaller velocity through the pump passages, give opportunity for very little lost energy in developing the velocity through the pump and in losing the resulting velocity head, and likewise little loss in friction through the passages. The acceleration of the water column through the pump is likewise small. It must be seen then that the main loss is in the passage through the valves.

It is evident from the result that the increased valve area is not of great importance, the loss being practically the same whether all the valves or two-thirds of the valves are in use. The velocity through the valve opening, given in the paper as 2 to 5 feet per second, cannot itself create a very big loss. This may be shown as follows: The loss of head through a submerged orifice is probably between 1 and 1 ½ times the velocity head due to the velocity through the orifice. For a velocity of 5 feet per second this would make a resistance of less than .5 feet of head. It is evident, then, that for the valve fully open the loss of passage through the valve openings would be less than was observed.

We must then look elsewhere for the source of this loss than to the resistance through a fully opened valve. One agency evidently is the tension of the spring of the valve, which results in the valve being but partially opened. This tension must be overcome by the dynamic pressure of a current of water through the valve opening. For a current directed against this valve, this dynamic pressure may be said to be somewhat less than twice the velocity head due to the velocity through the valve. It will be seen that this result is materially less than the pressure required to open the valve and hold it open against the ordinary spring. As a result, the valve will not open fully, or not all the valves will open. This necessary pressure against the valve will be obtained by the valve opening only slightly and by the resulting higher velocity through this smaller opening to such a point that the tension of the spring is overcome. This will result in an additional resistance of the water through this smaller opening above that directed against the valve, and hence a larger loss than for an orifice of the size of the valve area.

Now, let us see the effect of changing the valve area or the number of valves used. As the valves are made and operated, there is little difference in the tension developed in the spring, whether the valve is opened slightly or fully. Likewise it requires the same pressure per square inch to hold two valves open as to hold one. The work of the plunger against this pressure is then the same, whether two valves are open or one. Of course this pressure is not the only element of loss, and hence there is a limit to this apparent uniformity, for each reduction of valve area increases the resistance of the water through the opening, and this resistance will be greater than the pressure which holds the valve open. By the results of the paper, apparently little will be gained by increasing the valve area, for valves of this character, beyond a certain limit.

If, then, the springs of the valves are the chief source or agency of the loss, the remedy must lie in the change of the design of the valve, and the choice must be between simplicity, quickness and certainty of operation, and the use of a valve which will avoid the losses of energy caused by the spring.

If the above seems at first glance to controvert the principles of work and energy, in that the spring of the valve remains at rest after it is open, bear in mind that it is the plunger which furnishes the energy, and that the energy of the jet is wasted in friction.

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Western Society of Engineers.
Vol. VII. No. 1.—Plate II.
Mead—Some Experiments on Pump Valve Area.

# INDICATOR CARDS FROM PUMP CYLINDERS TRIPLEX PUMP.
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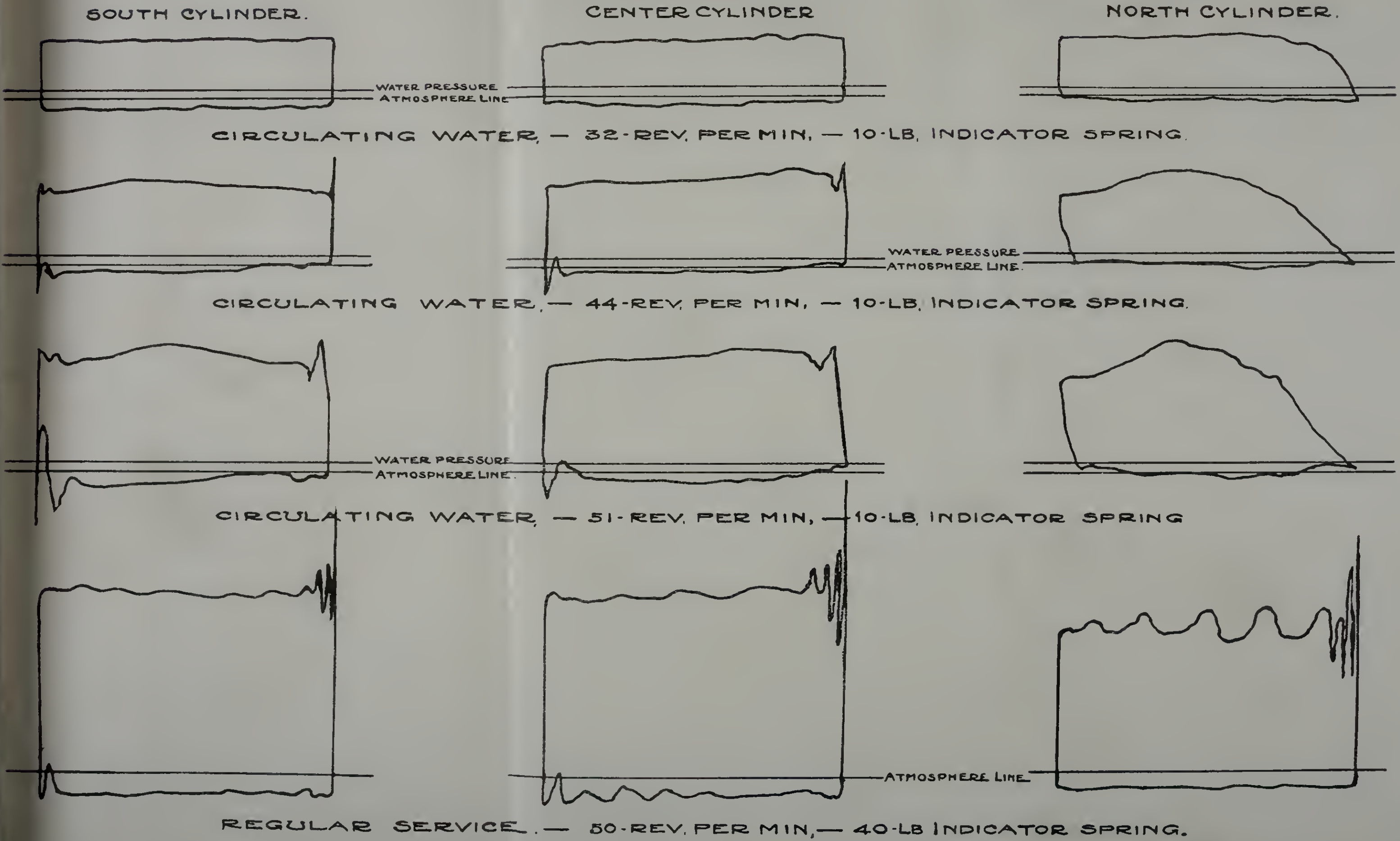

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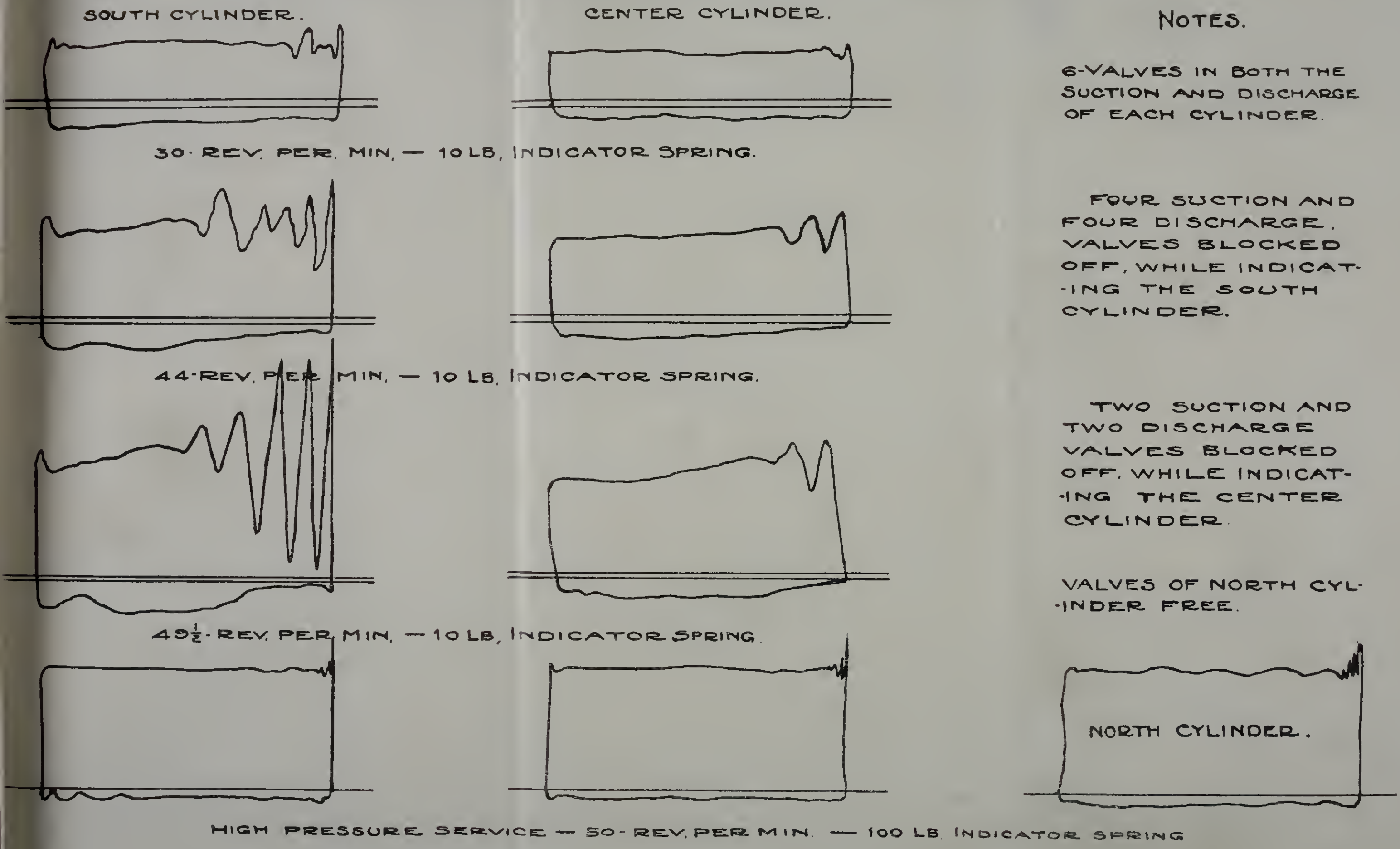


NOTES.

6-VALVES IN BOTH THE SUCTION AND DISCHARGE OF EACH CYLINDER.

FOUR SUCTION AND FOUR DISCHARGE, VALVES BLOCKED OFF, WHILE INDICATING THE SOUTH CYLINDER.

TWO SUCTION AND TWO DISCHARGE VALVES BLOCKED OFF, WHILE INDICATING THE CENTER CYLINDER.

VALVES OF NORTH CYLINDER FREE.

## CLOSURE.

*Mr. D. W. Mead*—The losses in the valves and water passages of this pump are undoubtedly due to a variety of reasons, and from the experiments it would appear that the loss mentioned by Prof. Talbot is undoubtedly an important one.

The small gain due to the increase in valve area would seem to show that the increase in valve area is only apparent, and is largely modified by the failure of the valve to properly open. For this reason, it would appear that we have, in this case, reached, and perhaps passed, the limit at which an increase in the free water area of the valve seat is profitable, for with the maximum free waterway, by which we had anticipated reducing the friction losses, we find practically no decrease in the total losses, and our conclusions must be that the decrease in friction loss, which would normally result from the increased waterway in the valve seat, is prevented by the failure of the valve to open to the necessary extent. If this is the case, it is apparent that we must either put up with this considerable loss, or secure the proper opening by the use of mechanically operated valves. There can be no doubt that this is at least the theoretical remedy necessary, which will not only reduce the friction loss in the passage of water through the valve, but will also decrease the slip due to the failure of the common type of valve to close promptly at the end of the stroke. Whether the gain will warrant the extra expense is another matter.

There are a number of points in connection with this plant relative to efficiency and economy which have not been discussed, but which, judging from the questions asked, may be of general interest.

1st. As to the probable cost of operation. Conditions were such that a test for the efficiency of this plant could not be made. From the nature of the machinery, however, a close estimate of the same can be had. It is estimated that the indicated horse-power lost in engine friction is 4 horse-power; the amount lost in pump friction, 6 horse-power; the power consumed in pumping water under domestic service, 10 horse-power; the valve friction, ½ horse-power, making a total indicated horse-power in the engine, when pumping under domestic service, of 20½ horse-power.

When rotating the water through the valves, the engine and pump friction will be practically the same as when pumping under domestic service; that is to say, 10 horse-power. The work of rotating the water amounts to 2 horse-power, making a total of 12 horse-power.

The capacity of each pump is 350 gallons per minute, or 500,000 gallons per day. The average amount of water used at Winchester is probably about 100,000 gallons per day. The total work required, therefore, to operate this plant each day will be as follows: 20½ horse-power for 5 hours = 102½ horse-power hours; 12 horse-power for 19 hours = 228 horse-power hours, or a total amount of work per day of 330 horse-power hours.

The amount of natural gas used for each indicated horse-power hour is about 14 cubic feet, or a total for operating the pumps one day, of 4,620 cubic feet. This amount at 12½ cents per thousand cubic feet, equals 57¾ cents per day, or $17.32 per month, or $207.84 per year. The actual cost of gas for pumping, varies from $15 to $18 per month.

2d. As to the saving effected by the use of the by-pass valve over using a relief valve to discharge the excess of water.

It will be noted from the above that it takes a total 20½ horse-power when working the engine under full load. When rotating the water only 12 horse-power is used, thus making a saving of 8½ horse-power for 19 hours each day, or a total saving each day of 161½ horse-power hours, a saving of about 35 per cent over the amount of gas which would have been used with a relief valve. At 14 cubic feet per horse-power hour the saving is affected of 2,261 cubic feet of gas per day, which, at 12½ cents per thousand cubic feet, represents a saving of 28 and 26-100 cents per day, or $103.15 per year.

3d. With the price of natural gas as low as at Winchester, would a stand-tower be economical in connection with this pumping plant?

From the statements previously made, it will be noted that the actual work required per day is 20½ horse-power for 5 hours, or a total of 102½ horse-power hours each day. If a stand-tower was used, the pump would be run to this capacity, and then shut down. The saving effected would, therefore, be 12 horse-power hours for 19 hours, or a total of 228 horse-power hours. At 14 cubic feet of natural gas per horse-power hour, this represents 3,192 cubic feet of natural gas, which would be saved if a stand-tower were used. This amount of gas at 12½ cents per thousand cubic feet, represents a saving which might be effected by a stand-tower, of 39 and 9-10 cents per day, or $146.00 per year. At 6 per cent this represents a capitalized value of $2,433. It is, therefore, evident that if the saving in fuel is the only item, then a stand-tower would not be a good financial investment. If, however, as is probably the case at Winchester, the use of a stand-tower would save the cost of one engineer, the financial conditions are changed. The saving, then, would be not only the $146.00 per year for fuel, but also the services of one man for 12 months at $60 a month, or a total of $720 for help. The labor and fuel saved would, therefore, equal a total of $866 per year, which capitalized at 6 per cent, equals the interest on a capital of $14,433.

A stand-tower of 100,000 gallons capacity would probably cost in Winchester about $8,000, while the saving effected would be equal to interest on $14,433. It is, therefore, evident that under such conditions, the cost of a stand-tower would be fully warranted.

4th. What saving, if any, is effected by the gas engines over a steam plant in which the natural gas would be used under the boiler?

In ordinary boiler practice a pound of steam is developed from 1,600 to 1,800 heat units in the coal, and in poor practice this amount will often increase to 2,000 heat units to the pound of steam. Gaseous fuel does not seem to give as economical results under the boiler as may be obtained from an equal number of heat units from solid fuels. It is, therefore, probable that 2,000 heat units will be a fair estimate of the amount of heat required under conditions at Winchester, to develop a pound of steam.

The best natural gas will run about 1,000 heat units to the cubic foot. It will, therefore, take under a boiler about 2 cubic feet of natural gas to develop a pound of steam. In the type of engine which would be used to operate a triplex pump in a small pumping plant, such as described in this paper, the steam consumption would be about 40 pounds of steam per 1 horse-power hour. The total amount of natural gas used would, therefore, be about 80 cubic feet per horse-power hour. If a direct acting duplex steam pump were used for this same service, about 100 pounds of steam would be required for each 1 horse-power hour, or a total of 200 cubic feet of natural gas.

The plant described may, therefore, be said to be operated on from 1-5 to 1-6 of the amount of fuel, which would be used under a boiler for the same type of pump, operated by a well designed small steam engine, and on about 1-15 of the amount of natural gas which would be used under a boiler with a duplex direct acting steam pump on direct pressure service.

## CXL.

# FIREPROOF GRAIN ELEVATOR CONSTRUCTION.

Jas. Macdonald, M. W. S. E.

*Read December 18, 1901.*

The designing and construction of grain storage buildings, commonly known as "elevators," is now undergoing a change as radical as that which created the modern "sky-scraper" a few years ago, and for precisely the same reason, that something more durable and efficient is desired.

The elevators in Cook County alone have a capacity of about 50,000,000 bushels, which taken at an average estimate of 50 cents per bushel for building and contents will show a total valuation of about $25,000,000, and a risk for which the insurance companies charge anywhere from $1.50 to $3.50 per hundred, and claim that they are losing money at that price.

There are few Americans who have not become acquainted with the familiar outlines of our grain elevator buildings, for they have a monotonous similarity to the casual observer, and while much ingenuity has been displayed in developing the effectiveness of these clumsy looking hulks, nothing has been accomplished in beautifying their outlines. The elevator building is therefore built for utility,—plain and simple. It is a collection of elevating, weighing and distributing machinery surrounded by a building, cut to fit the machinery requirements—even though the cut is sometimes a misfit.

The fundamental principle of our storage bins was invented several years ago when Joseph cornered the corn market of Egypt, and from that time until Joseph tried to do the same thing in Chicago, the principle has not been improved on.

The ordinary grain bin, or *silo*, as it is called in Europe, is a receptacle usually having its greatest dimension in its height, designed to receive loose or bulk grain at its upper end and to discharge same through openings in the bottom. The walls of the bin may be built of wood, metal or masonry, as the requirements or exigencies of the situation may demand. Wood being the cheapest and most available material in America, has been adopted almost universally. The amount of timber required in a modern terminal elevator ranges from four to five feet board measure per bushel of its storage capacity, so that one of our million bushel elevators along the Chicago River will contain from four to five million feet of lumber, which when once ignited seldom leaves any salvage for those carrying the risk. Taking the large terminal elevators—by which is meant those buildings erected at the termini of railroads or water routes—where the grain is transferred and stored for export, with the small country houses which are the outlying points of the grain business along the great railways, the fire record shows an average loss of, or damage to, one elevator building for every day of the year. The cheapness of our timber has been the controlling motive for its use in this construction, but the conditions are now rapidly being revised. Timber has advanced much in price, and other available materials such as steel and masonry—either in the shape of brick, concrete, tile, or combinations of these materials, have been reduced in price; hence the changing conditions of elevator building.

The modern elevator as ordinarily constructed has the storage divided into many compartments, ranging in capacity from 4,000 to 10,000 bushels and upwards each.

The necessity of, or desirability for comparatively small compartments or bins will be apparent when it is understood that many kinds, grades and separate lots of each kind of grain are stored in the same elevator building, each of which it is often desirable to keep separate, or in individual compartments. The smaller the bins the more closely can the total storage be utilized, as the different lots of grain when kept separate can be given bins that will more closely correspond with the volume of each lot, without loss of space. The bins at the bottom usually converge to the outlet spout at an angle that will permit the grain to run freely from the bin, without leaving residue.

The bin story of an ordinary terminal elevator is carried on a heavy frame structure at a sufficient altitude to allow the loaded cars to be brought under them and pass through the building. The operation of receiving grain from either cars or vessels is practically the same in all elevators. In railroad houses the cars are delivered to the elevator and are handled by car puller mechanism in placing the cars in the building opposite the elevator legs. These elevating machines, or legs, consist of a belt carrying buckets between a large pulley placed in the highest point of the elevator and a boot pulley placed in the lowest point of the elevator, which is ordinarily ten or twelve feet below the track level. The first elevation of the grain is usually sufficient to enable it to reach its destination, in part of the bins, by gravity. The cars are unloaded by two power car shovels, each car operated by one man, who carries a scoop, at the end of the shovel rope, back into the car. When he stops and gives slack to the rope, the mechanism of the spool pulls him with his scoop and load of grain to the car door where it stops automatically. The grain falls into the wide open hopper, or sink, built around the elevator leg, the outlet of which is directly into the elevator buckets. From the top of the leg it discharges by gravity through the garners and scales, where it is weighed, usually in draughts of a full car load, and is then spouted or conveyed by horizontal conveyors to the bins which it is to occupy. When the grain is received from the bins it is drawn from the lower outlet and either spouted or conveyed to the elevator legs, re-elevated to the top of the building, where it can be again weighed before shipment, or sent direct to the other compartments in the building. If the grain is to be shipped by cars it is dropped through a spout from such an altitude that the force of the fall will completely fill both ends of the car simultaneously. The operation of loading a car with 80,000 lbs. of grain will average from five to ten minutes. The same car could be unloaded in from seven to fifteen minutes. When shipped in vessels by water, the grain falls from the scales through suitable shipping spouts located on the outside of the building and reaching to the hatches, into which it can be delivered at at the rate of 15,000 to 20,000 bushels an hour for each spout.

In many elevator buildings the grain is treated to improve its quality by special cleaning, polishing, grading and drying machines. Where grain is received from vessels into an elevator building a specially constructed elevator leg, called a "marine" leg, is used. This is equipped with means for placing the leg in any hatch in the vessel and raising or lowering it as conditions of the unloading process may require, and delivering the grain inside of the building. These briefly are the functions of the modern grain elevator.

The quantity of grain to be handled in a given time with any given capacity for storage, determines the style and shape of the elevator building. If the handling capacity is small compared with its capacity for storage, the bins will cover too much area to enable the legs to fill them by direct spouting, in which case conveyors are used both above and below the bins, from and to the elevator legs for filling and emptying the storage.

As previously stated, wood has been the material mostly used in this construction. The plans show a typical modern elevator building as ordinarily constructed of wood. This particular example was erected for the Des Moines Elevator Co., and is now in active operation at Des Moines, Iowa. The foundation consists of a series of concrete piers supported on pile foundations. On each pier a timber column is erected, and all the columns are capped longitudinally and crosswise of the building with "long leaf" pine timbers 14 x 14 inches, and long enough to cover two spans. On the timber frame thus formed the walls of the bins are erected to the desired height. These walls vary from 10 inches thick at the bottom to 4 inches thick at the top, and are constructed of hemlock planks or boards about 1⅞-inches thick, laid in continuous lines across the building in each direction, and built up in successive laminated courses, and each course spiked to the one below it with 3 penny spikes. Bins of any desired size may be thus constructed at a cost from 5 cents to 10 cents per bushel for the bin enclosure only. The elevator legs and weighing machinery are housed above the bin work in a cupola usually somewhat narrower than the bin story. This cupola may rest immediately on the bin walls, as shown in plans, or may be supported independently by timber columns through the bins from the first story frame. The entire building is usually covered with corrugated iron, which is nailed directly to the bin walls on the outside, and to the sheathing of the cupola. It is questionable if this thin iron cover affords any real protection from fire. If the outside is exposed to an adjacent fire, the iron usually curls up and floats away on the breeze like card board. When the fire is started from the inside, which is the most common occurrence, the iron is of little value as a protection. The load to be carried by the bins, exclusive of their own dead weight, is about fifty pounds per cubic foot of contents. The distribution of this load is such that it is all carried on the walls, by the arching of the grain, excepting that portion resting on the bottom of each bin, which, theoretically would be represented by the grain carried by the bin bottom to a height where the angle of repose would join the vertical walls of the bin. The angle of repose is about 30 degrees for all kinds of grain, and if the walls are perfectly rigid all weight above this line is carried by friction on the walls with the grain arched from side to side.

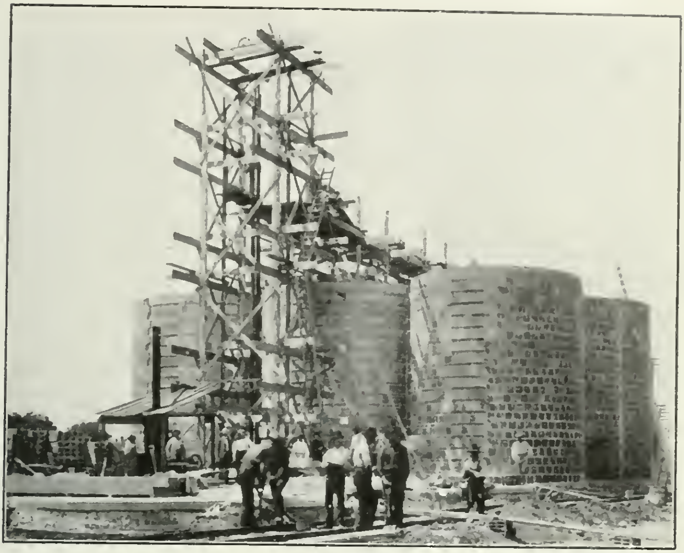
The wooden bin walls are not, however, perfectly rigid. The grain of the timbers being placed horizontal, and the joints between the planks not being a cabinet-fit there is always considerable settlement. Seventy feet of bin walls, erected with fairly dry lumber, will shrink as much as eighteen inches, making that difference in the height of the bin walls between the finished dimension and the dimension after settlement. In this case the bottom or floor of the bin would receive a heavier load than it would if the wall was rigid, particularly during the process of settlement, and its strength must be proportioned accordingly. It is thus that in filling a bin with grain when the bottom becomes completely covered all load on it ceases, no matter how high the grain may be carried, after the amount of grain on the bottom reaches the vertical walls. It is this peculiarity in the distribution of weight of grain that enables us to open or close an outlet valve placed in the bottom of the bin. It makes no difference in friction on the valve what depth of grain there may be above it. It will be as heavily loaded if located ten feet from the top of the grain as it would if placed one hundred feet below the top of the bin contents.

When grain is drawn from a bin the column immediately over the opening moves from the valve, clear through the mass to the top of the grain. On the top it continually rolls inwardly from the bin sides to the descending column so long as the grain is allowed to run. The last grain put in the bin is the first to follow the column out, and the first grain put in is the last to be delivered.

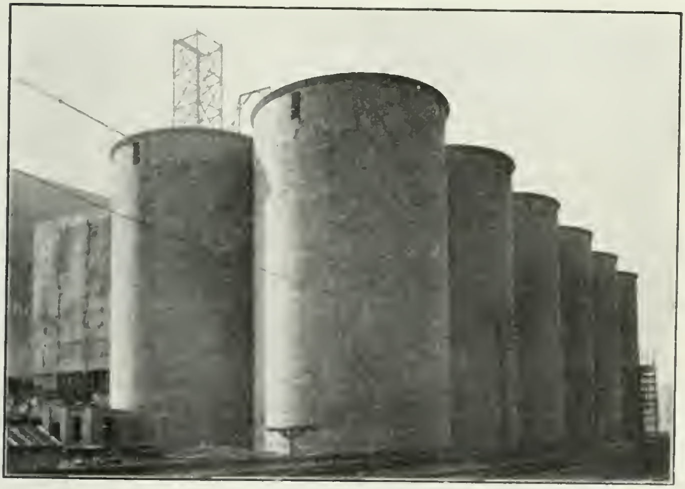
Substantial progress in the erection of fireproof buildings for housing and storing grain has been made within the last few years. In foreign countries brick and concrete have been successfully used, both for the construction of the silo, or bin system, and for the flat floor or warehouse system. There is at present being erected in Liverpool a grain elevator with 1,500,000 bushels capacity, the walls of which are of brick 100 feet deep, each bin averaging about twelve feet square on its horizontal dimensions. Several large elevators with brick bins have been erected at Odessa and Novorossisk, on the Black Sea in Russia. Concrete has been successfully used in other European countries, particularly Germany and Roumania. A large storage elevator has been completed, with concrete bin walls, at Duluth. The bins are cylindrical in form and placed a short distance apart, being connected together by a concrete wall so as to reclaim the inclosed space, for storage, between the bins

Tile Bins Under Construction.
Barnett & Record Co., Engineers and Contractors.

The Barnett & Record Co., of Minneapolis, has recently brought



Tile Bins Under Construction.
Barnett & Record Co., Engineers and Contractors.



Tile Bins Completed.
Barnett & Record Co., Engineers and Contractors

out a system of fireproof grain bin construction, consisting of a combination of tile and reinforcing steel members, in which hollow semi-glazed tile of special form is used. The walls are built circular in shape, and of various diameters and heights. They are formed by an ingenious method of bonding each course of tile blocks, which are about twelve inches in height and six inches thick, by means of courses of channel-shaped tile, the flanges of the channels standing upward to form a trough in which steel bands are buried in mortar flush with the flanges of the tile. The bins are built in courses of plain and channel tile alternately, first one course of segmental tile twelve inches high, which is capped with the channel tile, then another course, and so on, until the structure is completed. At the same time an outside protection shell of tile is brought up and bonded to the main body of the wall so as to form a perfectly water-tight shell and additional fireproof surface to the structure. The roofs are enclosed with skeleton steel construction, using book tile, fillers and finished with cement. The bins may be arranged in clusters, so as to utilize the interior spaces between them for storage. In these cases additional strength is given to the convex surfaces of the cylindrical bins by means of a series of rods, tieing them together across the storage space. The bottoms of the tile bins, formed of concrete or other masonary, may be left either flat or formed conical, so that the grain will discharge to the spout opening by means of filling, built up against the interior surfaces of the walls to an angle at which the grain will run freely therefrom, and finished with a concrete facing. The structures as thus built are exceedingly effective and durable, both from the point of view of service and freedom from fire risk.

Steel has been used for many years in an experimental sort of way for grain bins in this country. Until recently there has been a widespread suspicion that steel was not suitable for holding such sensitive material as grain, and that it would not keep it, owing to the condensation of moisture that must be given off under certain atmospheric conditions.

In 1861 a grain elevator was completed in South Brooklyn, N.Y., with the bins holding about 500,000 bushels, each bin twelve feet in diameter and about fifty feet deep. Some years later another grain elevator was erected at Girard Point, Philadelphia, with steel bins. Both of these elevators have been in successful operation since their completion, but the excessive cost, at the time they were constructed, discouraged further efforts in this line.

For many years after their erection the disparity between the price of steel and wood was too great to permit of the former being used as a material for grain elevators, and the popular idea that a steel or iron tank will always give off more or less moisture, was a powerful argument against its adoption. It has been found, however, that when steel tanks are enclosed so as to prevent a free circulation of air in the interior, that the danger from condensation is almost, if not quite, removed. Of late years the experiment has been made of storing flaxseed in large tanks of steel. his provedT very successful, and was followed by the construction of tanks for the storage of wheat and other kinds of grain with the best results. In cases where the tanks were built separate from the building, which contained the operating machinery, and holding from 50,000 to 150,000 bushels, the cost per bushel was not more than 15 to 20 per cent greater than the same storage room would cost in wood.

As a general thing it is not desirable to keep large quantities of grain in one bulk, and for public elevators and general warehousing of grains it is impractical. Grain must be kept in good condition while in store. If it gets out of order it frequently must be aired, or ventilated, by turning it over through the elevator legs and conveyors from one bin to another. It is, therefore, for example, more convenient to have 50,000 bushels in five separate compartments than to have it in one, for, if one portion of the 50,000 bushels gets out of order, in the five compartments, only one-fifth of the bulk would have to be treated, while if any portion of it got out of order in the larger compartment, it would all have to go through the airing process.

The demand for bins in terminal and public warehouses, varying in capacity from 10,000 bushels or less is imperative, and in the steel elevator recently built by the Great Northern Railway Co. at Duluth the bins are built of steel, and made rectangular, in order to give the requisite number and capacities in the division of the total storage. In this house the bins are made of flat plates, strongly braced and tied together from side to side to prevent buckling. It is almost impossible to get an absolutely rigid construction in rectangular bins by using flat plates exposed to such heavy strains, first on one side and then on the other.

Sometimes two bins in juxtaposition will both be loaded to their full capacity. The wall between them in this case would have no particular side strain, as the load would be balanced. If one bin is drawn before the other, the unsupported plates in the empty bin will show a movement by lateral pressure from the loaded bin. It would, therefore, seem that the most logical shape for a bin built of steel plates is the cylindrical, and in order to provide a bin storage that should have cylindrical bins of moderate capacity arranged in such a manner that the total space enclosed by them would all be available, a system of construction in which the plates of one cylinder are interlocked with those of adjacent cylinders, and incorporating the triangular space between them into bin storage, either as separate bins, or merged into adjacent bins, is shown herewith.

In erecting this work the vertical joints of the plates where the bins come in contact with each other are lapped. The horizontal joints are butted and covered with butt straps. Where the cylinders are in contact with each other the lap is four plates thick, and all riveted or bolted together. In erecting, three plates are assembled loosely on the ground, so as to form a section of the triangular spaces between the cylinders, and by bolting up these spaces, setting up three plates at a time, we build up the whole structure in one piece—corresponding to monolithic structures in masonry. The spaces between the main cylinders on the outside are reclaimed by enclosing them with flanged plates, having the same curvature as the other plates, bolted to the main cylinders, as shown on the plan, thus giving the exterior walls of the building a fluted or corrugated appearance, with the corrugations vertical and the corners of the building round, as shown in Fig. 1. This bin work is used either on a steel or masonry substructure. It is applicable to all forms and capacities of grain elevators, from the smallest country farmer's house to the modern terminal elevator of the largest capacity. In these buildings all the material is fireproof. The floor covering of the bins is made of concrete. The cupola, roofs, walls and enclosures of all kinds are of steel. All elevator legs, scales, garners, spouts, stairs, runways, machinery supports, and even the special cleaning machines when they are used, are built of steel.

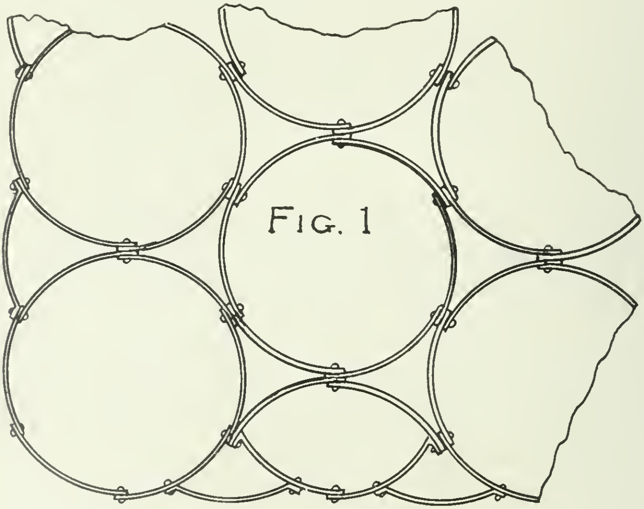
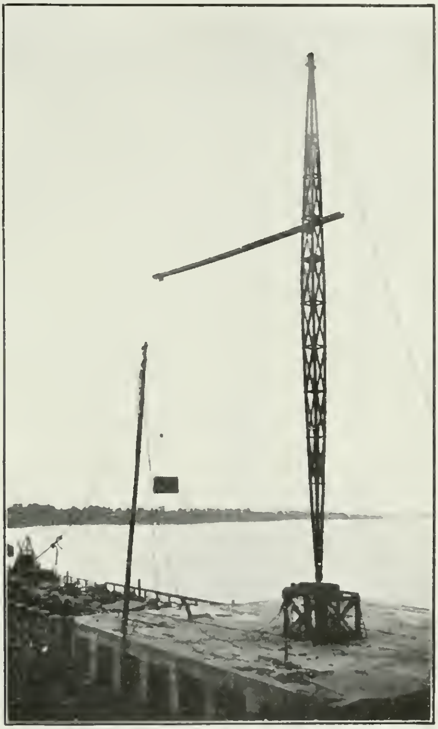


FIG. 1

Where the outside exposure of such a building would be particularly hazardous, it may be enclosed either with a brick or tile wall to protect the plates of the bin structure from direct exposure. When the first story or substructure is of steel the area for the bins is enclosed by brick walls.

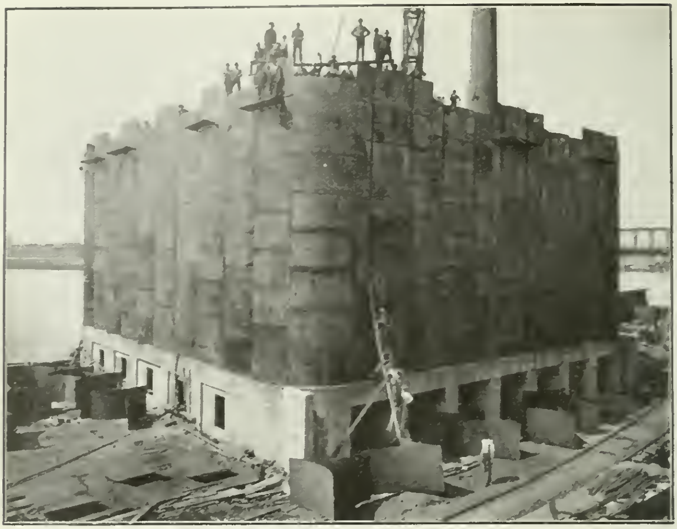
The C.,H. & D. Ry. elevator at Toledo, also the Lake Shore Ry.

elevator at Buffalo, N. Y., are constructed on this system with the foundations and first story built in concrete. Clusters of piles are driven under the spaces occupied by the piers, which are united at the top by groined arches, forming a solid table on which the bin work rests. The spout openings, with a steel spout in each, are built into the wall during construction. The floors and outside walls are of concrete, and when the first course of plates are erected on the foundation, concrete filling is placed inside to give the hopper form at the bottom of the bins.



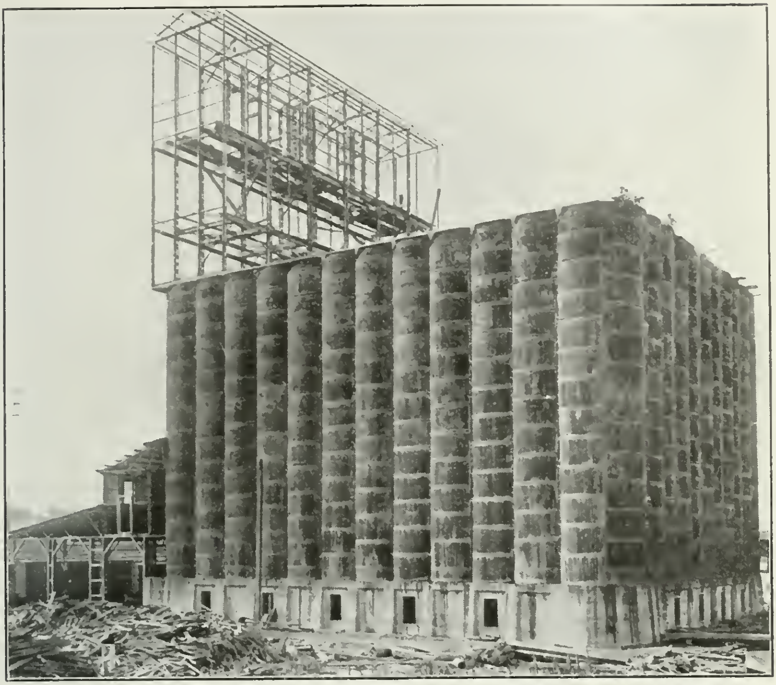
C., H. & D. Ry. Elevator "B", Toledo, O
Foundation and Derrick.

The relative merits for the different materials herein enumerated, will be finally determined only by the test of time. The selection of either will usually be governed by the price. The great weight and volume of bin walls constructed of brick will always be a powerful argument against its adoption where either concrete, tile or steel is available. The elevators erected in Liverpool and other European cities with brick walls have nearly one-fifth of the total



C., H. & D. Ry. Elevator "B", Toledo, O.
Bin Work Under Construction.

C., H. & D. Ry. Elevator "B", Toledo, O.
Approaching Completion.

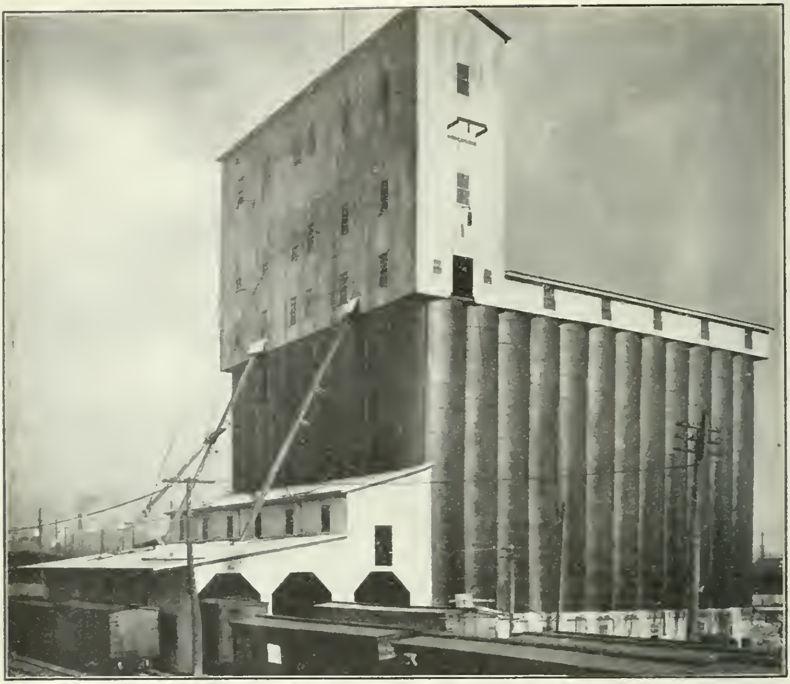


L. S. & M. S. Ry. Elevator, Buffalo, N. Y.
Bins Completed and Cupola Under Construction.

space in the bin story occupied by the brick. The ratio of weight between the walls and capacity is also objectionably great.

Concrete walls, bonded together by steel skeleton work embedded during construction, is fairly satisfactory, but the limitations of concrete construction, in our northern climate, to the warm months of the year, and its great dead weight, will restrict its use for this purpose. The tile construction herewith illustrated is more or less open to the same criticism as to the time of year in which it can be constructed. It has, however, the requisite lightness and strength, and no doubt will find favor, particularly in those cases where the business to be transacted in the elevator will permit the use of large storage compartments.

The steel construction has the advantage of being the lightest material per bushel of storage, of great flexibility in case of any derangement, workable in all seasons and places, and for all practical purposes, fireproof. It has been, however, subject to violent fluctuations in price, and necessitates more or less care in its preservation from rust on exposed surfaces, and could receive damage if built adjacent to an inflammable building unless covered with protecting walls of masonry.



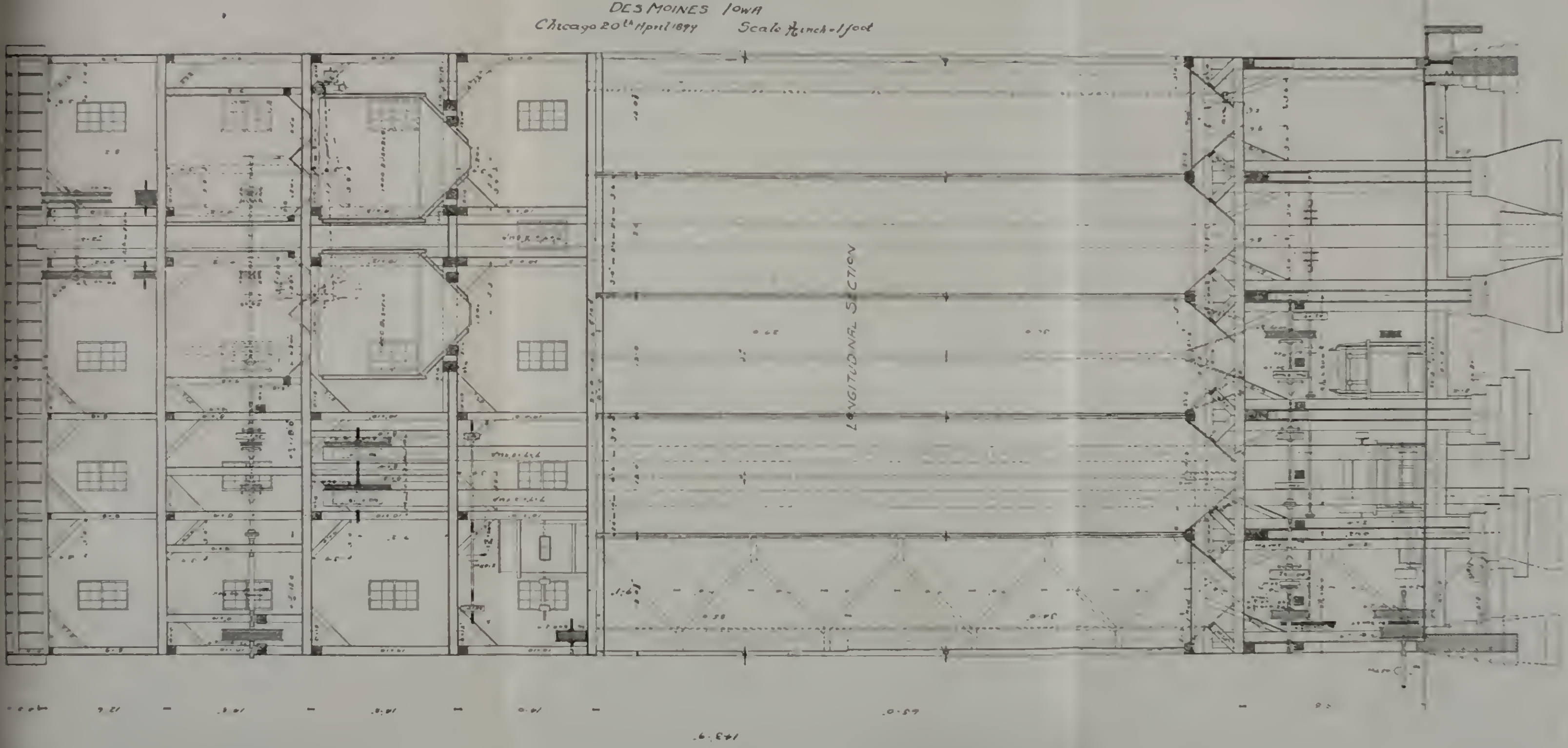
L. S. & M. S. Ry. Elevator, Buffalo, N. Y.
Approaching Completion

There is one feature, however, of a steel elevator building not possessed by any other, and that is, it may be at any time dismantled and removed without materially impairing its value. There are many elevators in the heart of the City of Chicago today that have outlived their usefullness, or rather the business has departed from them, and the ground they occupy has become too valuable for other purposes to be profitably occupied by the grain trade. They can only be economically removed by fire. If this condition should in the future overcome a steel elevator, it may be unbolted, loaded on cars, and carted off to a new location with small loss in the salvage.

## DISCUSSION.

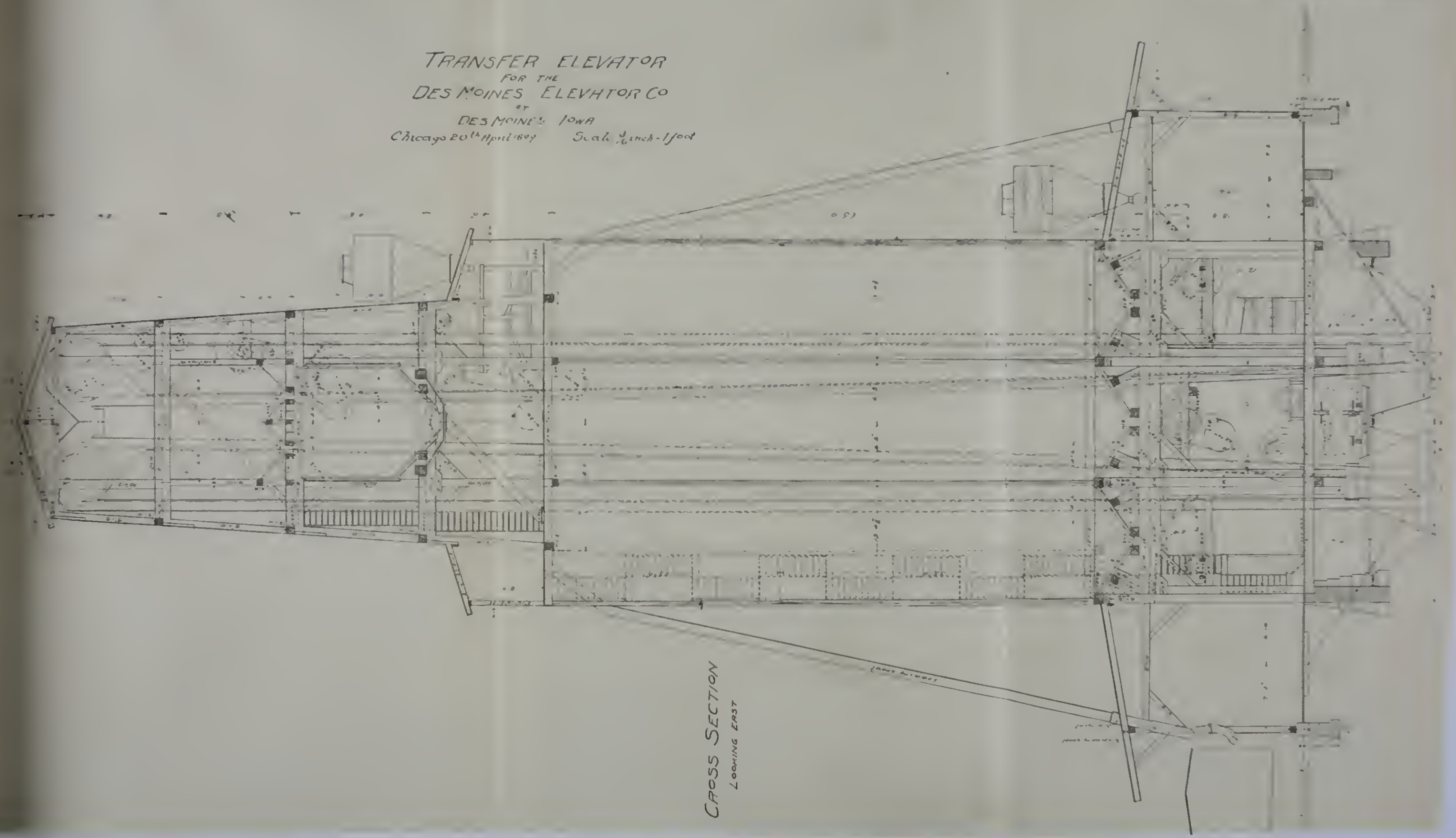
*Mr. Chanute*—I think we are very fortunate in having this clear, complete and practical paper presented to us this evening. I remember very well, not many years ago, that when foreign engineers came to this country and asked for information about elevators, we had none to give them from any of the engineering societies. I would ask Mr. Macdonald if he is familiar with the classes of

TRANSFER ELEVATOR
FOR THE
DES MOINES ELEVATOR CO
AT
DES MOINES IOWA
Chicago 20th April 1899 Scale 1/8 inch = 1 foot



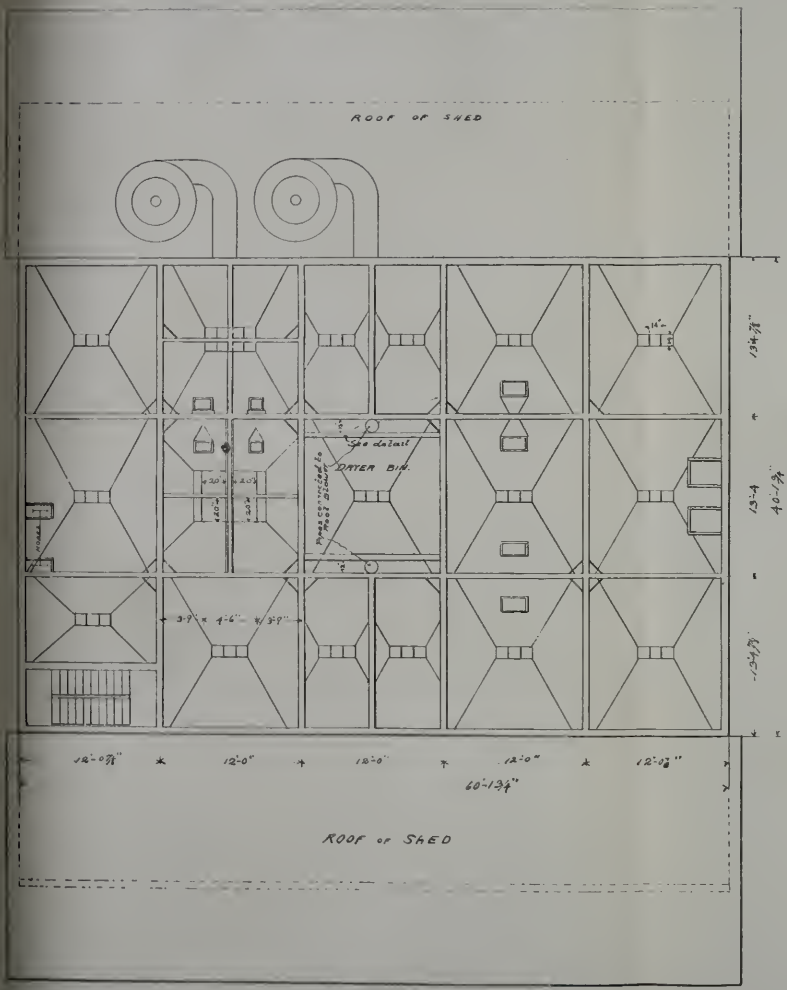
[illegible]
[illegible]
Macdonald—Fire-Proof Grain Elevators

TRANSFER ELEVATOR
FOR THE
DES MOINES ELEVATOR CO
AT
DES MOINES IOWA
Chicago 20th April 1897 Scale 1/16 inch - 1 foot

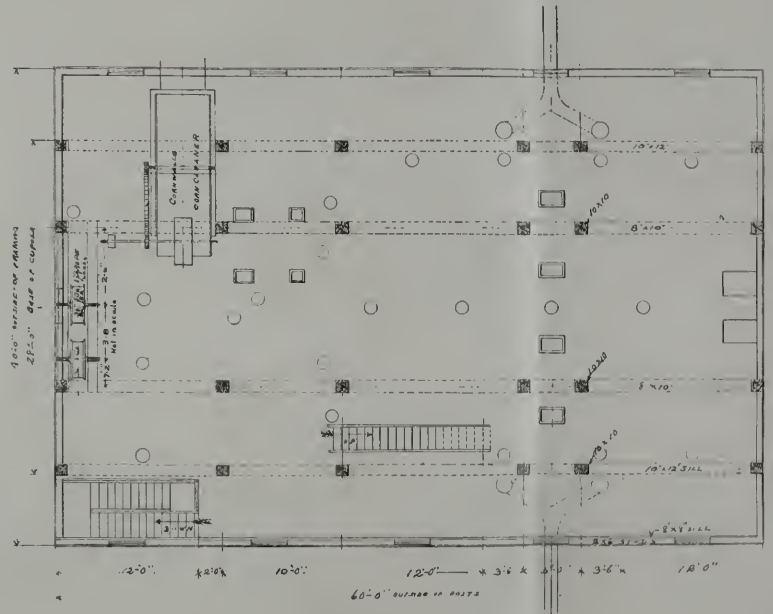


CROSS SECTION
LOOKING EAST

TRANSFER ELEVATOR
FOR THE
DES MOINES ELEVATOR CO.
AT
DES MOINES. IOWA.
Chicago 20th April 1899. Scale 3/16 inch = 1 foot.



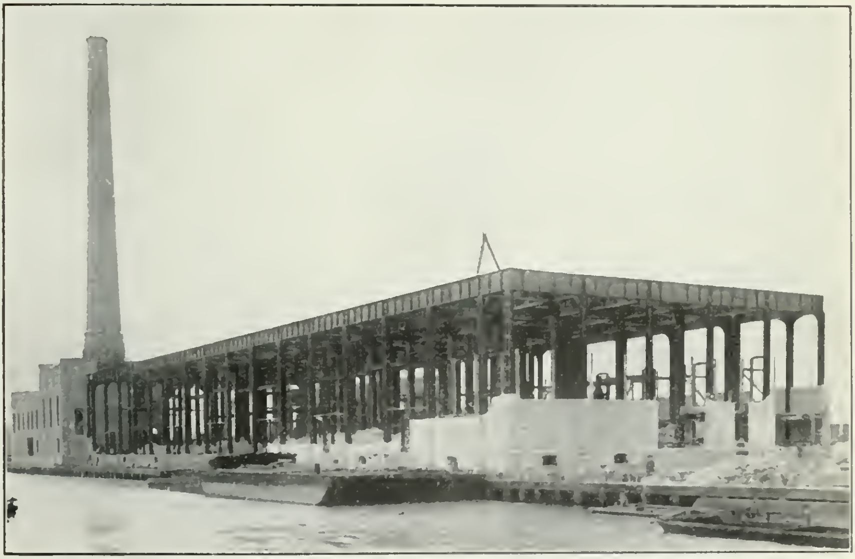
BIN PLAN



BIN FLOOR PLAN

elevators that were built at an early date in Liverpool, in which the iron construction was perforated like a nutmeg grater, air being forced through the bins to ventilate the grain, and in some cases to drive out the weevil.

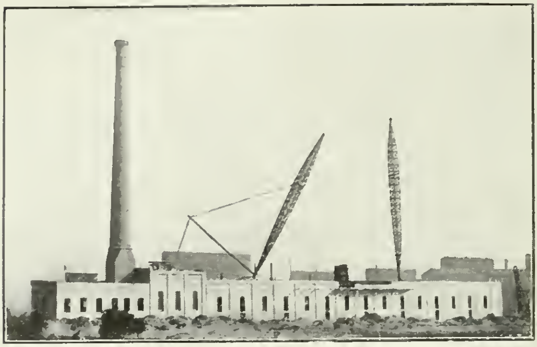
*Mr. Macdonald*—I am not familiar with that particular case, but I know of similar cases where it has been attempted to ventilate grain in bulk. Nearly all those experiments have failed for the reason that you cannot force a current of air through a large bulk of grain without drying the grain at the bottom where the air enters, too much. If there is any moisture in the grain immediately in contact with the first current of air, that is carried forward into the bulk of the grain and deposited, and by the time the whole bin of grain is dry through and through, the grain in contact with the first current of air will be too dry. The drying is not uniform.



Rialto Elevator "A", Chicago.
First Story Steel Work Erected.

*Mr. Chanute*—In 1889, when I was in Liverpool, the parties in interest at that time represented this process to be an eminent success. I afterwards saw an elevator in London built in the same way, which was also said to be a success, but I never heard what the eventual result was. I know simply that the parties had patented the method in this country, but they never sold any patent rights.

*Mr. Macdonald*—The reason they never sold any patent rights



Rialto Elevator "A", Chicago.
Erecting Derricks.

American Malting Co. s Elevator, Chicago.

is they found the method was not practicable. There are no such elevators in this country. The Americans have always been on the lookout for the best that is to be had. If there are any ideas in Europe to be imported to advantage, we do it very quickly.

*[illegible]* As a general proposition, the most economical way of handling the grain is from the top, I suppose. I would like to know just what sort of machinery you use for taking the grain out of the bins and discharging it into the elevator legs.

*[illegible]* In the style of elevator described in the paper,

where the cars do not pass through under the bins, the grain is brought from the bottom of the bins by means of a belt conveyor, and it will carry all the way from five to twenty-five thousand bushels per hour. The grain is carried to the highest point in the building so that it may reach its destination from that point, as in loading into the cars it is necessary to get sufficient altitude to give the grain force enough so that it will be driven to the very corners of the cars and load the cars full. This is done in a very few minutes, the door locked and the car shipped out.

*Mr. Warren R. Roberts*— How do you get the grain from these circular bins up on to this belt conveyor? Do you bring that up to the bucket elevators from the bottom of these tall bins?

*Mr. Macdonald*—Exactly. There is an opening in the bottom of each one of these circular bins. That opening is connected by a spout directly with the belt conveyor, and the grain spouts right into the buckets. The grain is elevated to the top of the building and spouted wherever it is intended to go, usually into the scales where it is weighed.

*Mr. Finley*—You discharge in each case from the bottom of your circular bins, do you not? Would it not be cheaper or more economical to discharge directly into the cars?

*Mr. Macdonald*—No. If you have a discharge from the bottom of the bins into the car, the grain would only fall over the car door, making it necessary for men to go in and shovel it back. You cannot have the bottom of one of these bins 75 feet from the ground. It would not be economical. It is more economical to lift the grain, and the weighing has to be done at sufficient altitude to give the grain force, when it falls, to distribute it into the cars without trimming.

*Mr. Condron*—In those buildings where the cars run under the bins, the grain is also elevated there in the same way, is it not?

*Mr. Macdonald*—The only advantage in having an elevator building so that the cars may pass through under the bins is in the handling capacity of the elevator itself. More cars probably can be unloaded because more elevating machines can be put in, in a given space. The elevator legs have to be placed, to begin with, in the elevator building, so that one car will be opposite one elevator leg always. The distances between centers must not be less than 40 to 42 feet; some as much as 48 feet centers.

*Mr. Francis Bainbridge*—I once heard of a scheme of exhausting the air from the steel tank for the purpose of killing the weevil, drying the grain and preventing heating. Was this ever successfully done?

*Mr. Macdonald*—There are special bins made for drying grain. It is now dried very successfully, but the fundamental principle of drying grain is that the grain must be stored so as to present a very thin wall of grain to the drying current of air. The current of air must not pass through a large mass of grain. The most successful drying machines today present a volume of grain to the drying current of about three or four inches, not to exceed that. It is found that if you try to force a current of air through a big mass of grain, the first grain in contact with the air gives out its moisture which is carried through the balance of the grain and deposited. In that way you cannot get uniform results. The grain must be dried uniformly. The bins for drying are built specially for that purpose. The grain is passed through such bins and the current of air is forced through while it is passing. It is exposed at the right time to carry out the moisture. Some grains have more moisture than others. Sometimes the grain is almost saturated. Sometimes it is slightly damp so that it would not keep if put in storage.

*Mr. Finley*—I understood you to say the Great Northern Road had built their bins hexagonal. Have they not also built circular bins?

*Mr. Macdonald*—I do not know that the Great Northern Road has built an elevator with hexagonal bins. They have not in the one I spoke of in Duluth.

*Mr. Condron*—They built one in Buffalo, did they not?

*Mr. Macdonald*—Yes, I remember that. They built circular bins that will hold a ship-load, 38 feet in diameter and 90 feet high.

*Mr. Finley*—Who was the first one in this country to introduce circular bins?

*Mr. Macdonald*—The first elevator of that character was the one I referred to as being built in So. Brooklyn in 1861. About ten years ago a big tank was built in Toledo by the Linseed Oil Company to hold their linseed. Linseed is an easy grain to keep and it is nearly all uniform in quantity and grade. They first built a tank that would hold 150,000 bushels and they found the grain kept very well; shortly after that Messrs. Churchill & Coon built smaller tanks for holding wheat. That is about seven or eight years ago, and since then a number of firms have built large tanks.

*Mr. Finley*—I remember six or seven years ago Mr. Foltz showed me some designs he was working on then for grain storage circular tanks, and I understood it was the first attempt at storing grain in any quantity in that way.

*Mr. Condon*—I suppose that was the plan of the Buffalo elevator built four or five years ago.

*Mr. Macdonald*—Yes, in 1897 or 1898.

*Mr. Roberts*—In closing your paper, Mr. Macdonald, you mentioned that one of the advantages in the steel construction was that the elevator could be taken down and removed; I believe that you used the expression that it could be unbolted and removed. Do I understand by that, that these elevators are bolted, or are they riveted?

*Mr. Macdonald*—All the work is bolted. The tanks are not water-tight; only on the outside. They are simply grain tight. It is not necessary to make any water tight joints, simply tight enough so that the grain will not pass through from one bin to the other. We find it more convenient to bolt, and they are just as strong. There is no reason why they should not be riveted, however.

*Mr. Roberts*—Do you use butt or lap joints?

*Mr. Macdonald*—The horizontal joints of plates are butted but the vertical joints are lapped. The outside of one of these buildings would show butt straps on horizontal joints.

*Mr. Finley*—What thickness of plates do you use?

*Mr. Macdonald*—It varies from 8½ pounds to the square foot at the bottom to 6 pounds at the top, diminishing as it goes up, for bins 16 diameter and 60 feet deep.

*Mr. Condron*—With reference to the preservation of these tanks, the inside of the structure for bins is not painted I presume, and all that is painted in any way is the exposed surface. Do you not paint any of the lap joints, where the metal laps, throughout the structure?

*Mr. Macdonald*—We paint all joints before erection, on the outside; all exposed joints.

*Mr. Condron*—I mean the lap joints all through the structure; those would not be subject to abrasion or polishing from the grain.

*Mr. Macdonald*—There is no painting on the inside at all. On the inside of the bins the joints are supposed to be always dry.

*Mr. Finley*—Are not the surfaces in contact of the lap joints in the interior of the bins painted before being erected?

*Mr. Macdonald*—No, not on the inside, but they are on the outside.

*Mr. Roberts*—Can you get these joints tight enough to make them moisture-proof, so that you will not have any trouble from moisture with that kind of joint?

*Mr. Macdonald*—We have no difficulty in making the outside joints weatherproof.

*Mr. Trumbull*—There were some tanks of this kind of construction put up in St. Paul that collapsed, were there not?

*Mr. Macdonald*—I do not know of any tanks put up in St. Paul that failed after being constructed. I understand there was a large grain tank, or series of grain tanks, being built up there that became wrecked in a storm. The walls are very fragile when under construction, and they are apt to be wabbly. A big wind storm came up and blew the structure in. It was not finished or it would have been all right. I do not know of any case where an elevator of this type failed after being completed and loaded. That is, a tank with a good foundation. If they have not a good foundation there is apt to be trouble from unequal settlement.

*Mr. Condron*—I think Mr. Macdonald's construction is admirably suited for bolted work. He used the word "monolith" in speaking of the construction, and that really fits the case. Each one of these cylinders is not built by itself. If these were independent cylinders, I should think it would be very essential to have the work riveted, as each cylinder would have to stand on its own bottom. I do not see why painting or some preservation of the metal should not be necessary in the case of the lap and butt joints, throughout the structure, for rust will certainly creep in there, which will have its effect in time. The tanks that are exposed to the action of the grain will be kept quite clean, of course, but in the case of the joints there is no cleaning action, and rust will get in and gradually eat those joints away. Have you ever taken down one of these tanks after it had been standing for any length of time?

*Mr. Macdonald*—No. The whole system is comparatively new. The longest time we have had one in use is about four years, but I went into this feature of construction quite carefully in the case of the elevator in Brooklyn, which I refered to. The conditions so far as deterioration of the metal, from rust, wear and tear, abrasion and everything of that kind, are concerned, are the same as in what we are building today. Those bins have been standing forty years, and from all I can see they are as good as those put up today. In the bins we are now building there is no painting at all. The moisture is excluded completely from these bins and the floor is put closely on top of them so as to bottle them up. The opening through this floor into which the grain is spouted is covered except when it is in use. There is no circulation of air, consequently no moisture can get in there. I take it that it is owing to the dryness under these conditions that the metal is preserved as it is.

*Mr. Condron*—You expect the grain to absorb all moisture?

*Mr. Macdonald*—If the grain was real dry it would. I remember the case of an elevator where they are storing malt. Malt is the dryest grain we know of. We found, after several months of use, that the malt on the bottom attracted moisture from the foundation. This was five or six feet below the bottom of the bin which was in contact with the grain that received the moisture. We did not have enough ventilation in the foundation, but there is no evidence of rust on the interior of the building at all.

*Mr. Finley*—It is almost a universal practice in metal construction to paint the surfaces in contact, and I do not see why there should be a departure from this custom in the construction of these bins. It is somewhat of a surprise to me, and also that you use such thin metal.

*Mr. Macdonald* In the cases you refer to it is intended that all parts shall be painted after they have been assembled. In this case the plates on the inside of the bins are not painted after erection, and the chances for keeping the metal that is in contact clean are just as good as they are in any other part of the plate.

*Mr. Finley* Well, are they? In the other cases you have them in contact with moving grain.

*Mr. Condron*—Suppose, however, you have a leaky roof?

*Mr. Macdonald*—That is possible. The floor, however, is watertight. The spout openings consist of cast iron thimbles that stand above the floor.

*Mr. Finley*—Are you prepared to state what is the comparative cost of the steel and wood construction?

*Mr. Macdonald* The relative cost of these buildings is somewhere in the neighborhood of 15 to 20 per cent greater than wood, depending somewhat on the price of steel and lumber at the time you make the calculation.

*Mr. Bainbridge* Does that include the brick work of the building, or does that refer to the tanks without the brick building?

*Mr. Macdonald*—I speak now of the metal inclosure, the part that holds the grain. The operating house may be very expensive or very cheap, depending on the amount of machinery that is in it, and the amount of grain to be handled in a given time.

*Max A. Zurcher (by letter)*—What is the maximum pressure caused by grain on elevator walls?

*Mr. Macdonald*—The maximum pressure caused by grain on the walls of bin containing it, is assumed to be equal to the weight of the grain itself, less the grain which would rest on the bottom of the bin to a height of its angle of repose in the center. Under this supposition we assume that the pressure is uniformly distributed on the entire area of the wall in contact with the grain.

*Mr. Zurcher*—Can it be taken as a percentage of the hydraulic pressure for a fluid of the same density as grain? If so, what percentage?

*Mr. Macdonald* The pressure of grain cannot be compared in any respect to the pressure of a fluid, as the arching feature which is so prominent in the grain storage is entirely absent in all fluids.

*Mr. Zurcher*—Is the pressure caused by grain in motion, when unloading only, or when loading and unloading at the same time, larger than pressure caused by grain at rest? If so, how much larger?

*Mr. Macdonald*—I do not think that there is any change in the pressure on the walls per square foot of the bin when the grain is in motion, either by loading or unloading. The pressure or suction action in the moving column above an open valve in any given column of grain is enormous, so much so that we always avoid placing any timbers or projections in the path of this movement. Wherever it has been done it has revealed a tremendous destructive pressure, breaking rods and large timbers, or anything else that may interfere with its movement.

*Mr. Zurcher*—Do different kinds of grain produce largely different pressures?

*Mr. Macdonald*—There may be a slight difference between the pressure of different kinds of grain. Linseed, for instance, flows very freely above its angle of repose. Unclipped oats and malt have a tendency to mat together, so much so that cases have been known where the grain has been drawn from the bottom of the bin leaving the arch intact, so that the whole mass of grain was arched over as if it was cemented together. When the arch is broken in this case the drop of the immense mass of grain is very severe on the building.

*Mr. Zurcher*—Are Prante's experiments made in Germany to be considered as reliable, or have they been shown to be wrong by other experiments?

*Mr. Macdonald*—I am not thoroughly familiar with Prante's experiments made in Germany, but as I remember, the results of his experiments showed that the column of grain which rests on a flat bottom has a uniform depth equal to $\frac{1}{3}$ of the diameter or horizontal dimensions of the bin. This experiment refers to a bin about 12 feet in diameter. I believe that the experiments of smaller bins indicated that the height of the grain resting on the bottom was somewhat less than $\frac{1}{3}$ of its diameter. In other respects I believe his experiments corroborated my theory.

*Mr. Zurcher*—Would the smoothness of iron bins cause the pressure to be larger than on wooden walls, and what has been the effect of projections in iron bins built to help the arching of the grain?

*Mr. Macdonald*—I do not believe it makes any difference in friction whether the walls containing the grain are smooth, as in steel plates, or rough as in wooden walls. I have never been able to discover that projections, or abutments, built out from the walls of the bin had any effect in helping to arch the grain. It seems to arch naturally against any surface that is inclosing it.

# CXLI.

## WATER PURIFICATION.

By Mr. P. A. Maignen, of Philadelphia.

*Read January 15, 1902.*

In this paper, which I have prepared at the request of your Secretary, I have not brought out all the subjects to a finish; I have more particularly made some points for you to think and work upon, so you will not be surprised if some parts are treated somewhat briefly.

The subject has been so well treated by the historians of the Art of Filtration in this country, there have been so many valuable reports lately on experimental filtration, that in order to interest you I shall have to go out of the beaten track and speak mostly on matters coming under my personal observation.

I must, however, in one respect remain in the track; that is, I must in this paper, as in all other papers of the sort, begin with allusions to the rudimentary means employed in the past.

The oldest kind of filter that we know of appears to have been the common felt bag; hence the name "filter," from the French "filtre;" Latin, "filtro," "filtrum;" English, "felt," fulled wool.

The felt bag is sometimes called "Hippocrates' sleeve." This name of course indicates that it was already used in the time of the Alchemists.

Filtering paper is a diminutive felt. All cloth filters and filter presses come under the same category.

In all these cases the separation of the solids from the liquid, or the act of filtration, takes place at the surface only; hence the rapid choking, necessity of extended filtering areas and frequent cleanings. They act essentially as surface filters with sometimes capillary action.

Filtration, with surface-acting filters, to be good must be slow. The efforts of inventors, working with this kind of filters, have all tended to multiply the filtering surface and to render the cleaning operation easy.

Porous stones, cut out in dish-like form, have been used for filtering water from time immemorial in Ceylon and Porto Rico. Very fine specimens are to be seen in the Berlin Museum of Hygiene.

There are, as you know, many filters made with porous stone (natural and artificial), porous porcelain, etc. These are also "surface" filters, but differ from felt in the fact that the passages for the water are "fixed" pores, whilst in the felt they are "flexible." If the pores in the stone and porcelain filters be too large, the purification is insufficient; if they be too fine, the filtration is distressingly slow.

Some say that porcelain filters are germ-proof; others maintain that they are not. Both are right. The porcelain, if fine enough and freshly sterilized through fire, gives at first sterile liquids, but according to European experts, the bacteria gradually "grow" through its thin walls, and the filtered water, after a certain number of days' use, is found to contain more bacteria than the unfiltered water. Hence the notion that all filters ought to be sterilized every few days.

This notion appears to be justified in the case of porcelain filters, but not so with "granular" filters, that give the best results the longer they are at work and the less they are disturbed.

The patent office classes filter applications mostly in two classes: "porous walls" and "granular beds." The former, of course, applies particularly to porous stone, porcelain and the like; the latter to filters in which gravel, sand, charcoal or other granular materials are used. The filtration here takes place in part on the surface and also in the depth of the granular materials. For instance, if you examine the sand of a filter bed, after a few months' use, at different depths, you will find the number of bacteria in the sand gradually diminishing; thus, distilled water used to wash sand taken two inches from the surface has 40,000 bacteria per c.c., whilst with sand taken four inches from the surface there are only 20,000, and at six inches 10,000 bacteria per c.c.

This would tend to show that useful work is done in granular beds not only at the surface but also in the whole depth. The suspended organic matter (which is food for bacteria) remains on the upper layer and the bacteria that penetrate below find little or nothing to thrive upon in the clean sand; they are gradually, as it were, starved out.

One old example of "granular bed" filters is to be found in India and is known as "Chatty." Three earthenware jars are held one above the other by a bamboo frame. The upper jar contains gravel, the middle one charcoal and the lower is for the filtered water. There are small holes in the bottom of the two upper jars, in which clean new straws are inserted. This allows the water to drop from one jar to the other and into the storage jar below.

Some household filters sold in this country, in France and England for many years, with coarse gravel and coarse charcoal between two sealed plates and with a small sponge at the top, were probably suggested by the "Chatty."

The value of charcoal, particularly bone charcoal, as an absorbent has been demonstrated by the French chemists many years ago. It has been very largely used in refining sugar and in small water filters, but it has not hitherto been applied to the purification of water on any very large scale in this country.

You all know how alum is used in India to clarify the water of the Ganges River; a piece of alum is put in the split end of a bamboo stick, it is then agitated in the water and the next day the water is clear.

The first moves in the filtration of water on a large scale were made, as you know, by Simpson in England, with his slow sand bed; by Darcy in France, who suggested the first "mechanical" filter; by De Fonvielle and Bourgoise, with their house filters, whilst Clark introduced his process of softening hard water in England.

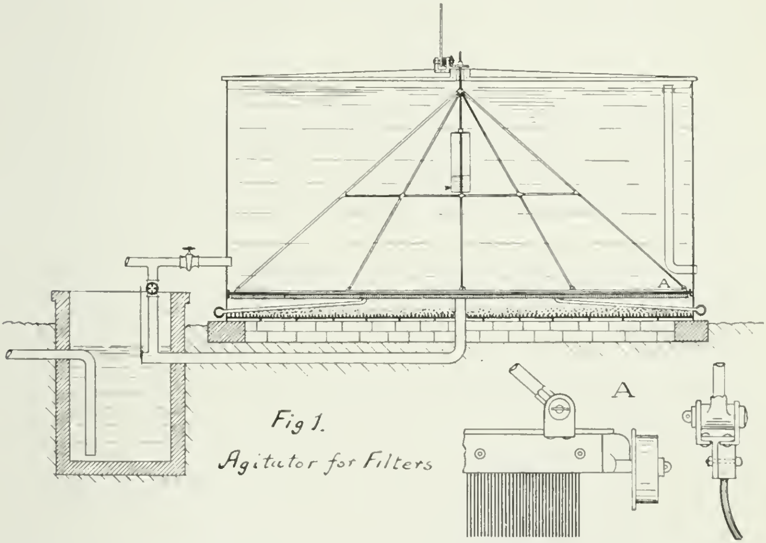


Fig 1.

Agitator for Filters

The idea of stirring up sand in filter tanks suggested by Darcy, and of which Fig. 1 gives a representation, is ingenious and has been largely developed in this country, but as far as we know, neither Darcy nor any other engineer or inventor has succeeded during the last fifty years in working successfully one single such mechanical appliance in the old countries. The expense and trouble of power and technical labor for operating machinery seem to have been insuperable difficulties.

The question of water purification was hailed in the middle of the Twentieth Century as the hygienic saviour of mankind.

Then came a time of doubt, when filters of every description were called "a delusion and a snare." But within the last fifteen years well-defined studies and observations have so clearly established the fact that a considerable reduction in the typhoid and general death rate has always followed the installation of filters in towns, public places, barracks, schools and private houses, that the enemies of filtration have been silenced.

Thus, for instance, at Cherbourg, in France, the water supply is drawn from a small creek, which is nothing but a ditch between two cultivated slopes; one set of pipes distribute the water to the town people and another set to the garrison. The city filters the water and the garrison does not. The following shows the difference:

TYPHOID FEVER—CHERBOURG, FRANCE.

| Year. | Deaths in the Garrison per 10.000 inhab. | Deaths in the Civil Population per 10,000 inhab. | |
|---|---|---|---|
| 1894 | 6.06 | 6.03 | No filters in use. |
| 1895 | 10.30 | 4.68 | Filters introduced. |
| 1896 | 27.87 | 4.61 | |
| 1897 | 23.45 | 3.63 | |

Water from the same source is given to both, but, as said before, the city water is filtered and that supplied to the garrison is not. You may draw your own conclusions.

Other diseases in the town have shown a considerable reduction:

| | Average of Years 1894-5-6. | Year 1897. |
|---|---|---|
| Measles | 55.3 | 5 |
| Diphtheria and croup | 14.6 | 3 |
| Diarrhœa and dysentery | 71.6 | 48 |

The general death rate has decreased six per thousand.

Nobody now questions the fact that typhoid and cholera are propagated by water. Epidemics of typhoid always follow great rainfalls. Cholera always travels along rivers, and many examples are cited, particularly among the British troops in India, where cholera has disappeared as soon as a change in location and water supply has been effected. Many other diseases are due to polluted water. Not least among these is tuberculosis. We are often reminded that we must not expectorate in public places, not solely because it is a bad habit, but also because the sputum dries up and spreads the germs of tuberculosis through the air. We are protected against these air germs by nature; the nostrils filter them out; the throat becomes easily irritated by dust and rejects it; but when the rain falls, it washes down not only the atmospheric dust but also the roads and fields; it stirs up the mud in ditches and rivers, and all this dust and dirt is carried into our water supplies. The spores originally in the dust soon become, as shown by Tyndall, bacteria after a few days' incubation in water. We are afraid of dry germs in the air, which are comparatively harmless, but we think nothing of swallowing quantities of water which is polluted by all the washings just alluded to.

Skeptics are to be found everywhere. I was once requested to install filters in a French military seaport (Lorient), where there were 200 deaths of typhoid fever in one month among but a few thousand marines. An Admiral in charge of a training ship in that port at first pooh-poohed the idea of water being the cause of typhoid fever. I suggested to him that, being a sailor, he must approve of cleanliness; that typhoid was essentially a filth disease and that if he should make sure that his men drink none but clean water, he would soon see a great improvement in their health. He took the hint, and it was not very long before he became the warmest friend of pure water.

The question now before you is *how* to go about purifying the water over which you have control or concerning which you may be consulted.

There has been of late a tendency to limit the modes of municipal filtration to one or the other of two specific processes, one known as the plain English slow sand system and the other the so-called "American" system. Citizens' committees have generally urged the former for fear of alum, but the people as well as water boards and councils are in this dilemma: they themselves do not know much about the practical working of filters, although they may have all the literature on the subject, and when they go deep enough into enquiries they find that what was true of the slow sand filter thirty-five years ago is still true.

Dupuit in 1865 wrote: "The process of artificial filtration such as is applied in London can only be considered as local solution, from which it is difficult to deduct general principles capable of being extended to other localities with certainty of success or guarantee of limit of expense. It is for this reason doubtless that until now there has been little application of the system in France."

If they turn to the record of the work of the so-called "American" system, they find that the people are decidedly opposed to it, because alum may be used in excess sometimes and remain undecomposed in the filtered water, and that when it is all decomposed, the water is made harder and therefore worse for soap, boiler, hygienic and culinary uses. Experts are consulted, they do their very best, but they do not assume any responsibilities. City engineers and consulting engineers are also handicapped in the following manner:

The natural aversion of cities to pay royalties deprives them of the use of the best things for a long time.

It is not so in the industrial world. For instance, a new machine, capable of economizing fifty per cent. of labor, is patented.

A manufacturer at once buys it; he can make twenty-five per cent. extra profit on the labor and undersell his old-fashioned neighbors to the extent of twenty-five per cent. of the labor.

But engineers of corporations do not as a rule think it the correct thing to apply for or own patents nor to recommend any patent article or process for fear of being suspected of partiality. They consider all their time due to their employers, who do not care to go in for experimentation with the people's money, and thus it is that no great discovery can be made by men who would if free probably find great things.

Consulting engineers are also in the same kind of difficulty. If they find improvements they are very much embarrassed with them; they cannot very well patent them, the cities for which they work cannot do so either. If they give the benefit of their ideas to the one town which employs them, all the other towns will copy the improvements without the slightest acknowledgment to the authors.

You can thus understand that professional etiquette and absence of protection must stand in the way of improvements.

Great principles can only be proved by the expenditure of much time and much money as well as brains, and it is only right that for a short time at least the sacrifices made in finding and proving inventions be protected by law. Thus and thus only can real progress be insured, and it would be a great advantage for this country if municipal engineers as well as consulting engineers could spend some of their own time and of their own money in experimenting for themselves without fear of their conduct being considered unprofessional.

It used to be said "time is money." Now we may add "the prize is for him who runs fastest."

I have therefore much pleasure in putting before you as many new ideas as I can, in order that the whole subject be ventilated, and all I desire is that there may be a rush to the patent office for securing protection for as many improvements as can be found in the art of filtration.

The art is sometimes spoken of as if it had reached the highest point of efficacy, when in reality it is still at the very bottom of the ladder in an economical and scientific sense.

Let us then now lay before you the wants as we understand them and see what are met by recent improvements and what still remain to be studied.

Before proceeding, however, with the question of filtration, I would like to allude to a subject that has not received sufficient attention in this country: I mean the question of lime in water.

You will find that wherever the water is hard, gout, gravel and various other kinds of arthritic affections are prevalent, whilst in soft water districts these disorders are practically unknown. For instance, in Scotland, where the water is soft everywhere, it is stated that in all the Scotch hospitals during fifty years only two cases of gout were observed, and it happened that the patients were brewer draymen. Hard water fills up the hot water pipes with scale. Boilers become incrusted and the scale opposes the transmission of heat, the plates become overheated and too weak to resist pressure. To this cause are to be attributed most of the boiler explosions. The soap does not dissolve in hard water; tea, soup and other infusions are very poor.

In the words of a Brussels Pharmaceutical Congress, "Hard waters form with the chyle an abnormal medium for hematosis; they fatigue the kidneys and incrust the articulations."

It was to remedy this defect in water that Clark, a Scotch professor, devised what is known as "Clark's process of softening hard water," and which is applied in several cities in England.*

## DOMESTIC FILTRATION.

However perfect the water from the city mains may be, the importance of having absolutely pure water to drink, particularly for children, is so great that no home or establishment where people live should be without a filter. If the town water is already filtered, the house filter will have less work to do, but it may at times be very useful. Metallic impurities may be given to the water by the house pipes and fittings. This is particularly the case in the west central parts of the United States and abroad, where the service pipes are of lead. Many cases of lead poisoning by city waters are on record, as in Sheffield and Huddersfield, England. If an accident should occur at the municipal filtration plant or in the main pipes, the house filter will protect you.

I do not propose to make a complete course on domestic filtration, but I should like to say enough to help you in making a good selection.

To be satisfactory, a domestic filter must be capable of removing from the water not only all suspended matter, but also all color and all bad taste. It should also be capable of removing dissolved organic matter and dissolved metallic poisons, such as lead.

A filter that makes the water clear and does not remove the bad taste is only half a filter. It does not purify the water, however well it may clarify it.

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*The Clark process consists in adding "milk of lime" to the naturally hard water. This acts upon the soluble bicarbonates contained in the water, absorbing one portion of the carbonic acid and producing the insoluble monocarbonates. These can be removed by sedimentation in large tanks. See "Water Softening and Purification," by Harold Collet, page 63. Spon & Co. London and New York. 1896—[Ed.

The worst impurity usually found in drinking water, whether drawn from wells or rivers, is dissolved organic matter or sewage. A good domestic filter must be capable of removing it. To ascertain if it does so, take a clean glass bottle with glass stopper, fill it with filtered water, add a few drops of potassium permanganate so as to give the water a faint pink shade, and let it stand a whole day or night. If the pink color remains, then the water is pure; if the color becomes yellow or disappears altogether, then there is organic matter in excess and the filter is not perfect. Of course the same experiment should be made with the unfiltered water. The greater the pollution the quicker the color will disappear.

Here is another simple test to apply when the town water has neither bad taste nor bad color: Add a crystal or two of sulphate of iron to the water so as to make it taste bitter; filter, and if all the taste is taken away, then the iron also is removed, and if the dissolved iron is removed, there is little doubt but that the bacteria in the water are also eliminated.

If a filter is submitted to a bacteriological test, it should be made to work at least a month in an ordinary manner before the bacterial test is applied.

The materials used in the filter contain, when new, air spores which become bacteria after they are wetted by the filtering water, and it takes a good long time before all these "constitutional" bacteria have worked their way out. I showed at the Convention of the American Society of Civil Engineers at Niagara Falls how a charcoal filter receiving during one month practically sterile water,

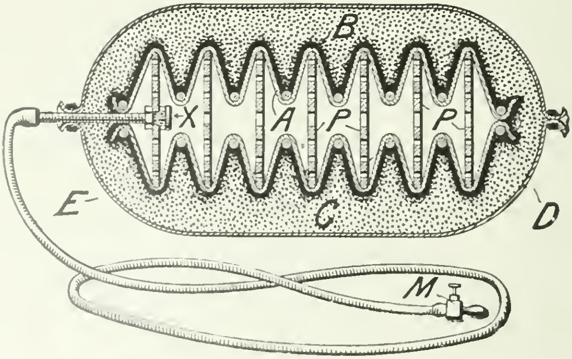

FIG. 2. SECTIONAL VIEW OF A MAIGNEN FILTERING ORGAN.

A is a special abestos cloth arranged in concertina shape by means of porcelain discs P P which distend the sack and abestos cords which are seen constricting it.

B is a thin layer of finely powdered Carbo-Calcis.

C is a thick layer of granular Carbo-Calcis

D is an outer Asbestos Cloth or Sack

gave at first a large number of bacteria in the filtrate, but after a month the filter had cleansed itself, the water then applied had thousands and tens of thousands of bacteria, but the filtered water remained day after day and for many months practically sterile; the filter never became foul, it simply ceased after six months to give the quantity desired, and it had to be cleaned.

The acknowledged existence in new filters of ordinary harmless bacteria has caused the Army Medical Department in Washington and the best experts in Europe to test filters with specific germs. For instance, it is known that the "bacillus prodigiosus," which develops a distinct red color on agar-agar cultures, is not often met with in water. This specific bacillus is added to the water to be filtered, and its presence or absence in the filtrate is easily ascertained.

We will throw on the screen presently a filtering organ, Fig. 2, made up of two porous walls with "flexible" porous-asbestos cloth, and two granular or charcoal layers, one in particles the size of granulated sugar, the other ground as fine as flour. Filtration takes place from the outside to the inside; the water first strikes an open asbestos cloth which is felted, as shown in Fig. 3, then the coarse charcoal, afterwards the very fine charcoal, and finally a somewhat close and very felty asbestos cloth, as shown in Fig. 4; the passages—capillary and granular—growing closer as the water penetrates deeper.

This filtering organ, as we will show presently, removes lead and organic matter as well as suspended matter.*

If any member of the Society will raise a discussion on the question of domestic filters, I shall be glad to have my say, but I think at present we better deal with the more important problem of supplying the filtered water to the people who cannot, will not, or care not to have the filters in their houses.

In other words, what is it that municipalities ought to do to give the people pure water?

This will depend mainly on the resources of the city and on the interest that councils may take in the matter.

### FILTERING FOUNTAINS.

When in the middle ages in Europe spring water was brought into cities, it was not distributed into every house as now; it was placed at the disposition of the public with monumental fountains in the

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* A test was shown to prove the action of the filter in separating a salt of lead from the solution. The presence of a salt of lead (the acetate) in a jar of water was demonstrated by the reaction of chromate of potash, producing an opaque yellow precipitate—that was readily seen by all present. The water which passed through one of these domestic filters from the same jar—containing the lead salt in solution—did not show this characteristic precipitate of chromate of lead upon adding the reagent—thus showing that the acetate of lead had been removed from the water by the action of the filter.—[Ed.

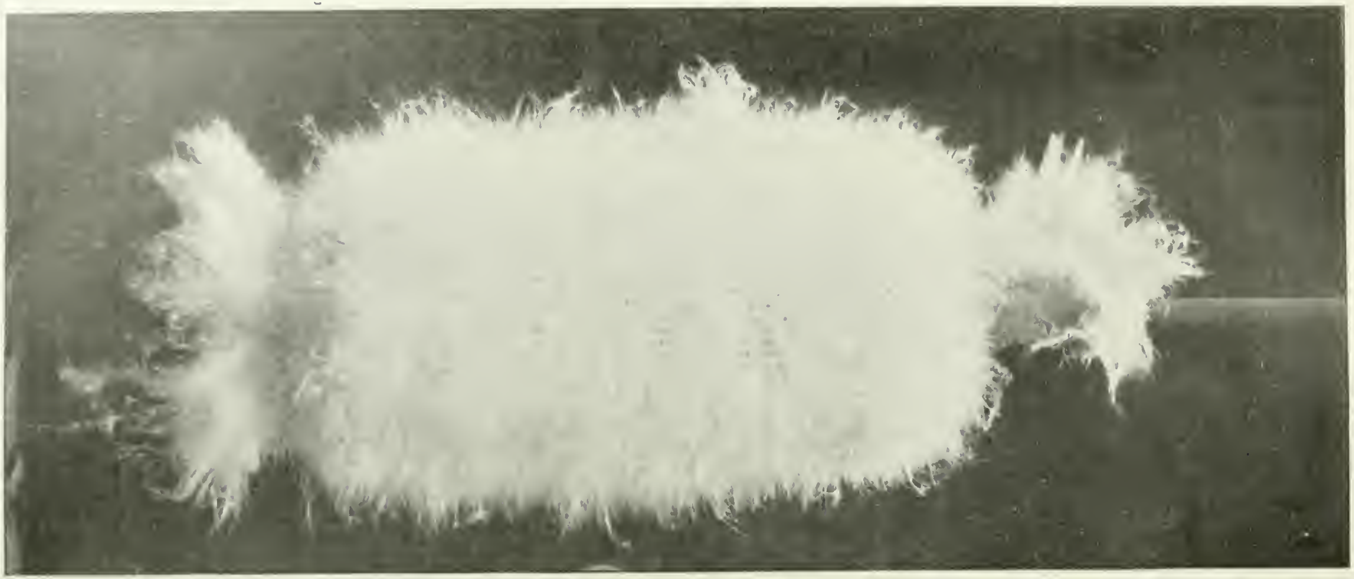

FIG. 3.

Appearances of a Maignen Filtering Organ in water. Observe the hairy appearance of the asbestos felted cloth. These loose fibres fill the meshes of the cloth and prevent the mud penetrating.

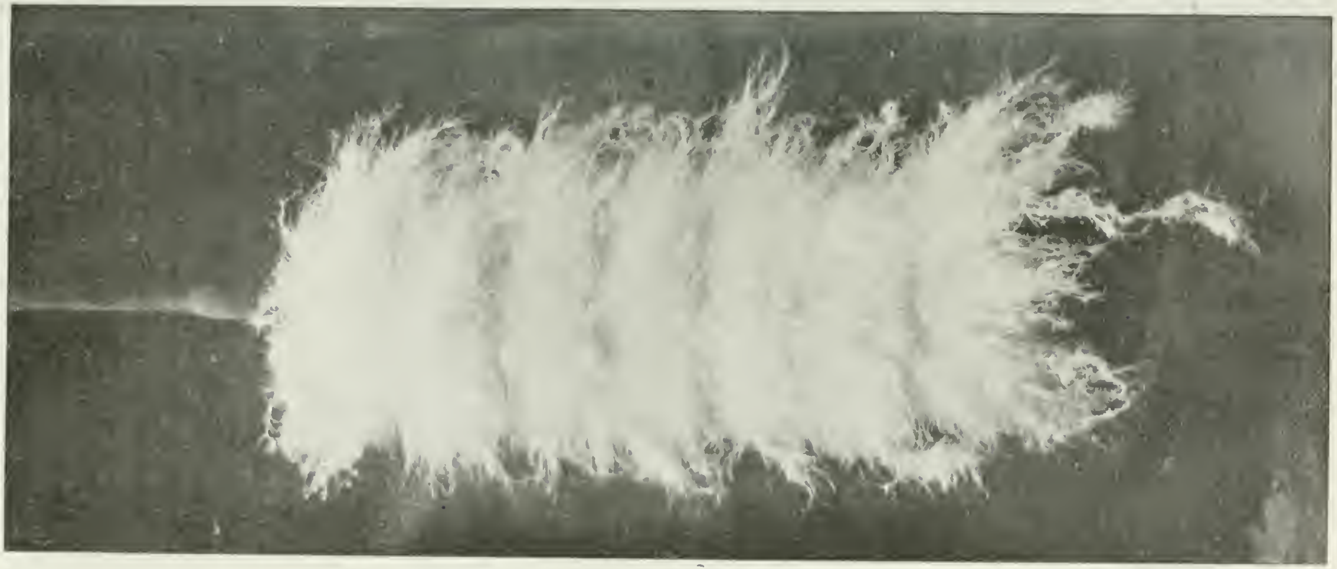

FIG. 1.

Appearance of the core A in water, before it is coated with the finely powdered "Carbo-Calcis." The filtration takes place by capillarity different districts. Later on hydrants were placed on the public streets at almost every corner. Thus in Cherbourg, with a population of 42,000 inhabitants, there are 150 public hydrants, where the people come to fetch water in buckets or jars for household use.

In this country there are a few drinking fountains in different cities for man and beast, but the water is generally so bad that they are very much neglected, because the public at large has grown afraid of plain unfiltered water.

I would therefore venture to suggest that American municipalities should imitate what has been done in France in many cities in times of epidemics—that is, install in the affected districts public filtering fountains, and preferably, of course, all over the city.

The filters may be placed in monumental fountains like those of Cherbourg, France, or underground, as in Nantes, France. Such a filtering fountain (Fig. 5) for a public supply of drinking water has been placed in Germantown (Philadelphia) by the councilmen of that ward, for the benefit of their constituents, at the time of a typhoid epidemic there.

What is wanted is that pure water should be placed at the disposition of the people, for them to use or not, as they please.

When really good water is to be had in a public place, mothers fully appreciate its benefits. For instance, once at Cherbourg I stood by one of the filtering fountains whilst it was being cleaned. A woman came with six empty bottles, intending to fill them with filtered water. She was told by the workmen that she could not have filtered water, that she had better go to the hydrant close by, which at that time had yet raw water. She sharply replied, "No, sir; I have a child sick at home," and she walked some blocks to get filtered water at another fountain.

In Philadelphia a certain number of these public filtering fountains were installed last year. They are so well appreciated that in the Italian quarter, for instance, there are regular fights to get at the pure water spigot at meal times.

At Lancaster, Pa., when the town water is roily, a sight worth seeing is to watch the crowd of men, women and children waiting their turn to take pure water from a filtering fountain erected in front of the City Hall.

Good filtering fountains in a city are like pure springs in the country, the people quickly appreciate them. Of course they must be of such capacity as to permit buckets and jars being filled as well as single cups.

In Paris, when cholera was reigning in 1892, filtering fountains were installed in the affected districts and produced very good results.

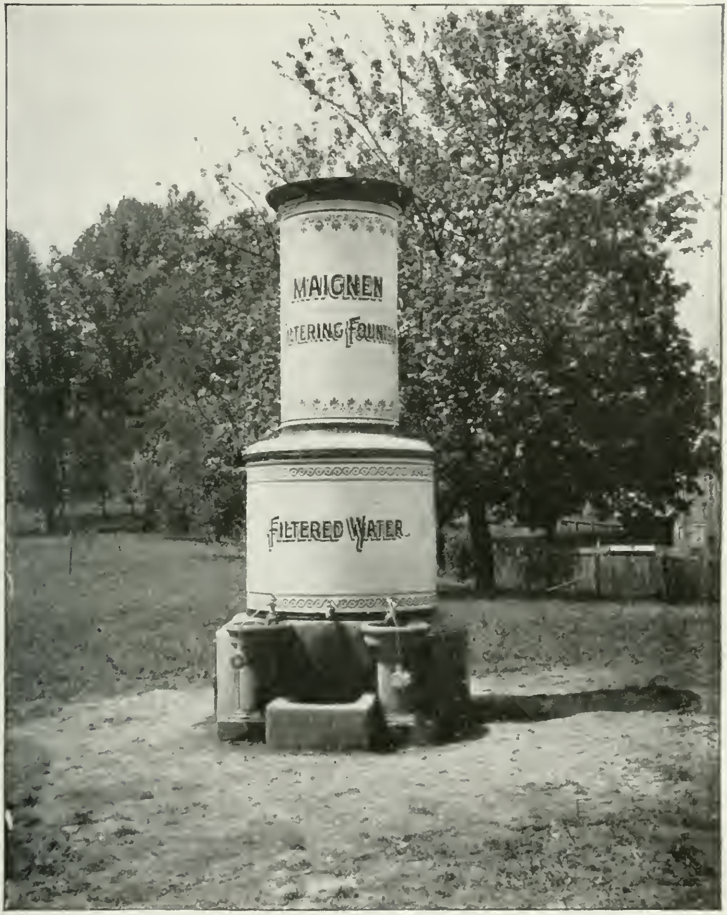

Fig. 5.

At Argenteuil, a suburb of Paris, cholera broke out in a district inhabited by poor families. Water could only be had from a single hydrant delivering raw river water. The mayor requested us to install a filtering fountain in forty-eight hours, and the hydrant was shut off. Immediately afterwards the cholera ceased in that district whilst it was raging in all the surrounding country.

## CITY WATERWORKS.

Of course this is at present by far the most pressing need. This country is rich enough to filter all the water that is distributed in cities, whether it be for drinking, for bathing, washing or even for watering gardens and streets. The quantity of water now used or wasted per capita is simply fabulous. In England it used to be es-

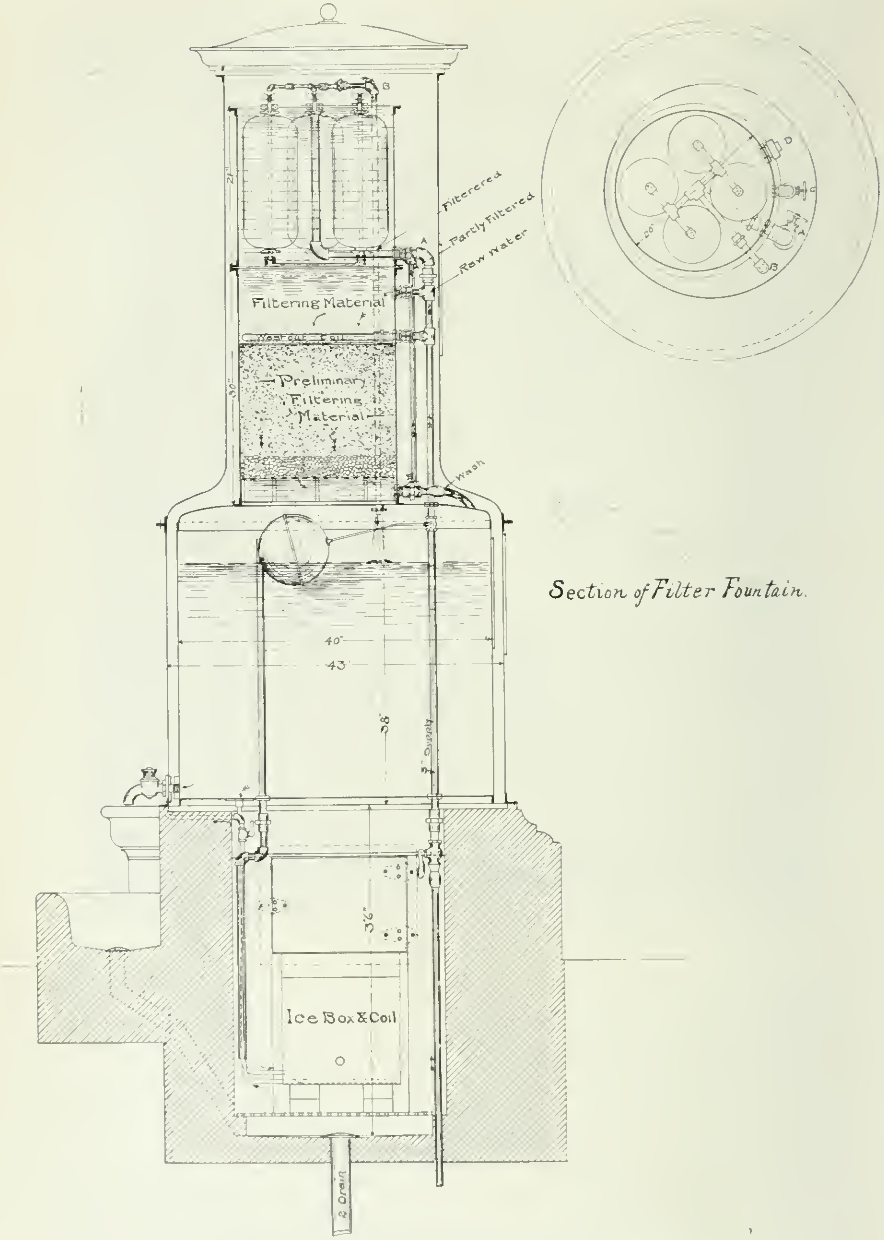

FIG. 6. A SECTIONAL VIEW OF SUCH A FILTER.

timated a big allowance to provide thirty gallons daily for each man, woman and child. In Philadelphia, the quantity now provided is over two hundred gallons per capita.

One of the present sources of waste would certainly be stopped if the water were filtered. When the water is dirty, housewives let it run to waste a long time in the vain hope of cleaning the pipes. If the water were always clear there would be no temptation for this waste. Another modern source of waste is to be found in the kind of filters used in large buildings; I mean those that have to be washed daily by reverse current. In the washing operation a very considerable amount of water is wasted.

Leaving the question of waste aside, two considerations present themselves : Should we recommend a double set of pipes, one for filtered water and the other for unfiltered water, or should we have one single set of pipes and *all* the water filtered?

Then should all the water be perfectly purified so as to amount practically to sterilization, or would a less perfect clarification be admissible for the general supply, with a secondary operation in filtering fountains or stations in the different wards? In this case there might be filter houses as there are power houses. The large mains would be tapped for a supply to the filters and new pipes would distribute the filtered water in the houses of each ward.

The people would willingly pay an additional cost to have pure water brought into their houses for drinking, bathing and cooking. In Paris there are two sets of water pipes. One delivers the raw river water, at twelve cents a thousand gallons; the filtered and spring water is delivered in the other set of pipes and is sold at twenty-four cents, and the rate is raised to forty-eight cents a thousand gallons to those who use it for elevators or industries, in order to prevent the noble water being used for base purposes and leave a sufficiency for house consumption.

Leaving these different considerations to be settled by those most interested, I now propose to conclude my paper by assuming that all the water has to be filtered and that the only question before us is *how* a town should proceed for the purification of the whole of its water supply.

The first question of course is that of finance. There are very few cities in the United States that could pay for permanent improvements of this kind out of its ordinary resources, and it is usual to issue bonds or borrow the money in some way or other for filtration plants. Then the people are called upon to say "yes" or "no" to a proposition for a loan; they have often refused to authorize indebtedness for this purpose, because they have not had sufficient guarantees that the results promised would be attained. In all these cases there was no responsible party or corporation behind the project; the quality of the filtered water might be perfect or it might not; hence the numerous rejections of such propositions. I believe that if a corporation with a perfect system, easily demonstrable, were to propose to cities to install with its own funds filter plants guaranteed to perform satisfactory duties, charging a given price per million gallons filtered and giving the cities the option of purchasing the plant when it had shown itself fully equal to its duty, such a proposition might be very acceptable to many cities.

They could easily apply, for instance, a part of the revenue from water to pay for its purification and there would be no need for loans, or if loans had to be resorted to, it would be only at such time as the public would have found out that the filtration plant was working satisfactorily, and then they would not turn down the loan.

The next question in order, is the character of construction best adapted to the case; should it be of a permanent or temporary character; should the filter tanks be made of wood, for instance, and the house over them a frame building, or should filters and filter house be built of concrete, brick or steel?

The settlement of this question is to be left in the hands of the interested parties, who will decide according to circumstances.

The last and most important question of all concerns the nature or quality of the water to be dealt with and the system to adopt to obtain the best and safest results at the least expense for installation and operation.

The water supply may be, for instance, like that of London, from a sluggish river in a grazing country, with but few days in the year when the water is roily and with provision made by means of artificial lakes to avoid pumping the roily water on the filters.

Such water filtered through a so-called slow sand filter at the rate of 1.6 or 2,000,000 gallons per acre per day, although much improved, is not altogether satisfactory, and some fifteen years ago, weekly bulletins were issued in London stating that the water of such a company was clear, that the water of another company was yellow, another brown (seen through a two-foot tube), and others again contained "moving organisms." When an epidemic reigned in London it always was worse in the districts supplied with the poorest filtered water.

It may be very well for councils, water commissioners and citizens' committees in this country to say they want to do as others have done and try no experiments. They should be told that the circumstances are not the same, that the water and climate are different. If the filtration by a certain process is practicable in a city that consumes 30 gallons per head each day, is it as practicable when 200 gallons per head are required? Is not the difficulty of securing sites greater? Each problem has to be taken as a whole and dealt with on its merits.

You as engineers have a right to use your own judgment and advise accordingly.

If the exact copy of what has been done in London, Berlin or Hamburg were all that is wanted, enough is published in text-books to give out a contract without consulting any engineer; a draftsman and a foreman would do it all.

But these plants are not necessarily perfect; the once-famed Berlin Stralau Filters have been abandoned; they never gave water exempt of color.

The plain slow sand system of water filtration has thus been described by Dr. Kemma (of Antwerp) at the Convention of the American Society of Civil Engineers in 1900 in London: "A heap of sand, water is poured on top and extracted from underneath. It is worked by a foreman, who knows of course how much water he pumps on the filters, but who cannot always tell how much each particular filter is doing, its speed, etc. Generally the filters are left to settle that between themselves." And he adds in a satirical sense, "This is the acme of simplicity."

This is how it appears to outsiders, but the man who has worked such filters knows it is not as easy as it looks. He knows that when he starts a filter he must throttle the outlet so as to check the flow first to 500,000 gallons per acre per day, then 1,000,000 and later on 1,500,000 gallons. If he should start his filter full speed, the water would carry its dirt right through. He has to open the outlets more and more as the "run" progresses (unless automatic devices are provided, which do not always work as they are supposed to), and if he gives half a turn too much to his valve, he may spoil his filter for several days. When the river is in flood, the mud that goes on the filter penetrates deep into the sand. Later on when he cleans the filter he does not like to take all the dirty sand out. It sometimes amounts to two inches; that would be too much to remove at a time, and so he takes off only ¾ or 1 inch. The next run is shortened and the filter becomes more and more packed until the whole of the sand has to be taken out.

There are many other difficulties met in practice that render the system anything but a complete success with American waters. If there is fine clay in the water, the finest particles go through the sand; if the water is discolored by a stain, such as those of the Eastern States, a very small portion only of the color can be removed by sand. The lot of the foreman of a plain slow sand filter is not always a "happy" one.

The following are the improvements which we deem necessary to adapt the slow sand system to American waters:

The filters should be always covered, because with open filters no work can be done during frost, rain or snow.

When filter beds ½, ¾ or 1 acre in size have to be cleaned, a large force of men are required, in order that the filters be not out of service too long. If the men have to be idle and receive no pay in bad weather, only inferior labor can be secured, and they do not do the work in a satisfactory manner. During the warm days of summer algæ grow in open filters and the sand cakes when exposed to the sun's heat. During freezing weather the filters cannot be cleaned. The cost of removing ice sometimes exceeds $2 a million gallons, spread over the whole year. This would pay more than the interest on the expense of covering the filters.

The style of covering adopted in this country consists in groined arches with ventilators. I do not care for this kind of roof, because it is very heavy, requires very strong foundations, and above all, because the operation cannot be easily watched, light is required for cleaning and dressing the surface, and artificial light is expensive and unsatisfactory. I prefer a filter house with plenty of daylight and elbow room for the men who work.

I have shown that it is not necessary to have more than two feet of sand and one or two feet of water over the sand, and the questions of positive and negative heads have no significance in fact. The walls of the filter tanks need not be more than 4 ft. 6 in. in height instead of 6, 8 or 10 feet as now constructed. I prefer dividing the fifters in small sections of about 1-20th acre, not only because small filters can be better controlled than large ones, but also because they take less time to clean, the work can be done by a smaller number of men permanently employed, and a much smaller proportion of the plant is idle during cleaning operations. With the large filters provision is sometimes made for 25 or 33 per cent. in excess of the requirement to insure the desired quantity of water.

But the greatest of all improvements I want to bring under your notice consist in preparing the water for sand filtration by depriving it of the greatest possible amount of mud previous to its admission on the filter. Sedimentation reservoirs, holding 24 or 48 hours' supply, do not remove more than 25 to 50 per cent. of the mud at the best of times, and under certain circumstances they do not appreciably improve the water. This is the case when the sediment is very fine and also in warm weather when algæ, or other organic growths, are likely to exist. I have found it very much better to submit the water to a preliminary filtration through what I call a "water scrubber."

By this preparation an average of 80 per cent of turbidity and 90 per cent. of the bacteria can be removed at a cost which is less than the interest on the settling reservoirs and their maintenance.

Then it has occurred to me that an artificial filtering membrane, made by depositing on the filter bed with the first water that goes on it, a light fibrous material, such as asbestos fibre, a further quantity of turbidity and bacteria can be retained in the proportion of another 80 per cent. of the turbidity and 90 per cent. of the bacteria left in the water after scrubbing.

To give its full capacity to the artificial filtering membrane I prefer placing on the sand a layer (about one inch in thickness) of pea size pebbles or gravel. This holds off the fibrous membrane, bridging it, as it were, and affording further room for the mud, if any should pass through the membrane.

The sand then has so little to do that it can do it well, and for a long time without cleaning.

Thus, for instance, a water containing an average of 4,787 bacteria per c. c. comes out of the scrubber with 250 bacteria and out of the filter with 13 bacteria, a removal of 94.7 per cent. by the scrubber and 99.9 per cent by the complete system.

The scrubber can go three or four months without attention or cleaning and the filters themselves fully two months.

The scrubber goes at the rate of 60,000,000 gallons per acre per day and the filter at the rate of 6,000,000 gallons. The gravel and sand that may be dirty are entirely removed each time, cleaned and replaced, so that each operation is begun with perfectly clean sand, which insures the speed, whilst the absence of previously retained mud prevents the pollution of the lower portion of the bed.

When the sand is the only factor in the act of filtration it has to be somewhat fine, and in washing it there is a considerable loss of fine particles, estimated at 15 per cent. of the total sand washed. When the sand is only one of four factors, the effective size of the sand need not be so fine; a coarser grade can be used.

In the slow sand filters erected in this country the quality of the sand has not received sufficient attention; the quantity required and the slowness of its action making the question of price of great importance. But by obtaining 6,000,000 gallons per acre per day instead 2,000,000, thanks to the preliminary treatment alluded to, we can afford to pay $3 or $4 for the sand instead of $1.25, $1.50 or $2 per cubic yard, as usually estimated. My notion is that the expense should not be spared in the materials that do the work, but we should endeavor to avoid all complications and accessories.

This improved slow sand system of filtration is particularly adapted to such waters as that of Chicago, New York, Philadelphia and Washington, but for water containing a stain or bad taste arising from decomposing vegetable matter, or containing an excess of sewage, I would recommend the use of charcoal. Charcoal is a granular material like sand, but it is porous and sand is not. It has the quality of taking away the color and bad taste of the water and much greater speed can be obtained than is possible with fine sand. I will show you presently several examples of the use of charcoal, but those that will be of the greatest interest to you are a project made for water having in the fall a very bad taste, caused by the growth of Amœboidea, and an installation made for the purification of 1,000,000 gallons of Schuylkill water in the City Hall of Philadelphia.

By the use of the scrubber and of the charcoal in the gravity filters the speed of filtration can be raised to 24,000,000, 36,000,000 and even 60,000,000 gallons per acre per day with a loss of head not greater than six feet, whilst under pressure, as in the Philadelphia City Hall plant, the speed can be raised up to 120,000,000 gallons per acre per day with perfect results and with a loss of head inferior to ten pounds.

The Philadelphia plant alluded to receives water with an average of 16,685 bacteria per c. c. The scrubber reduces the number to 215 and the filter to 15 bacteria per c. c., a removal of 98.6 per cent. due to the scrubber and 99.9 per cent. due to the complete system. This plant shows an example of what could be installed in the line of the supply mains in cities. These are results which I think worthy of your attention.

There are some waters that are so bad that they may require two scrubbers instead of one, and I believe all waters could be satisfactorily treated in this manner without coagulants, but I am, however, prepared to use coagulants if the water needs it absolutely, and the coagulant I prefer is a mixture of alum and soda, or more correctly, sulphate of alumina and soda carbonate. These two reagents neutralize one another in the water so that the water itself remains neutral. This should be introduced in the water shortly before it enters the scrubber.

The reaction is complete in a few moments and the flocculent precipitate coagulates on the elastic layer of the scrubber. A small quantity is sufficient, and this only when the water is very bad.

When the water is hard and needs softening, it has been usual to treat it with lime when the hardness is due to bicarbonate of lime, soda being added when the hardness is caused by sulphate of lime. These reagents have been habitually used in a liquid form.

This has been quite successful not only for water destined for boilers, but also for drinking, cooking and all other higher usages in mansions, hospitals and private houses.

The question of water purification should be particularly interesting to the people of Chicago, not only for their own water supply, but also because it may help you to settle the vexed question raised by the city of St. Louis. The good people of the latter city accuse your drainage canal of polluting their water supply; they urge that, whereas previous to the opening of your river they might

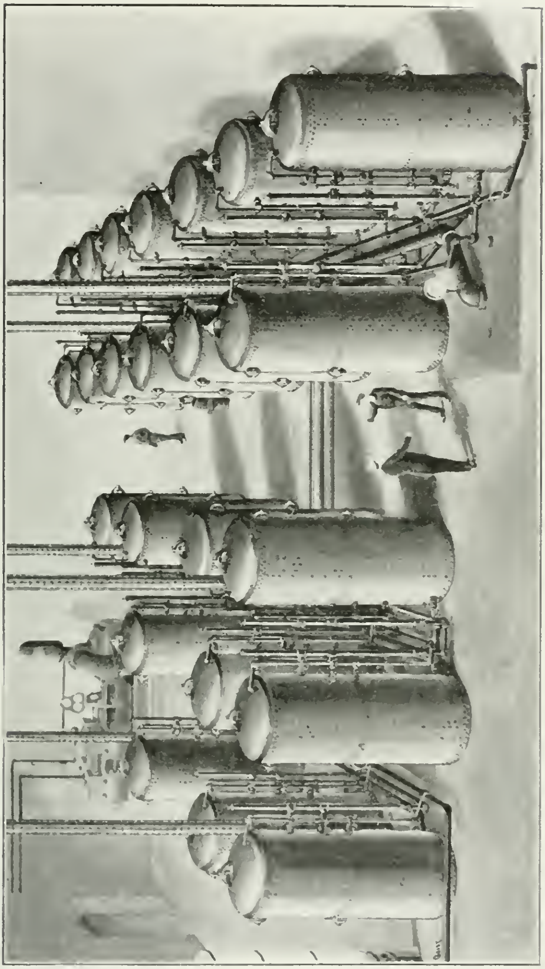

FIG. 7. GROUP OF FILTERS FOR 1,000,000 GALLON CAPACITY IN CITY HALL, PHILADELPHIA.

have purified the Mississippi water in a satisfactory manner by the means then known, now they declare themselves unable to cope with the excess of organic matter which they say comes from your sewage. They seek other sources, which are to cost $20,000,000 or $30,000,000, and they want you to bear a portion of the expense.

You can tell them that all spring waters are nothing but filtered water; that it is not beyond the power of man to purify even the worst polluted water as well as mother earth, by employing improved processes of water purification; that an additional improved

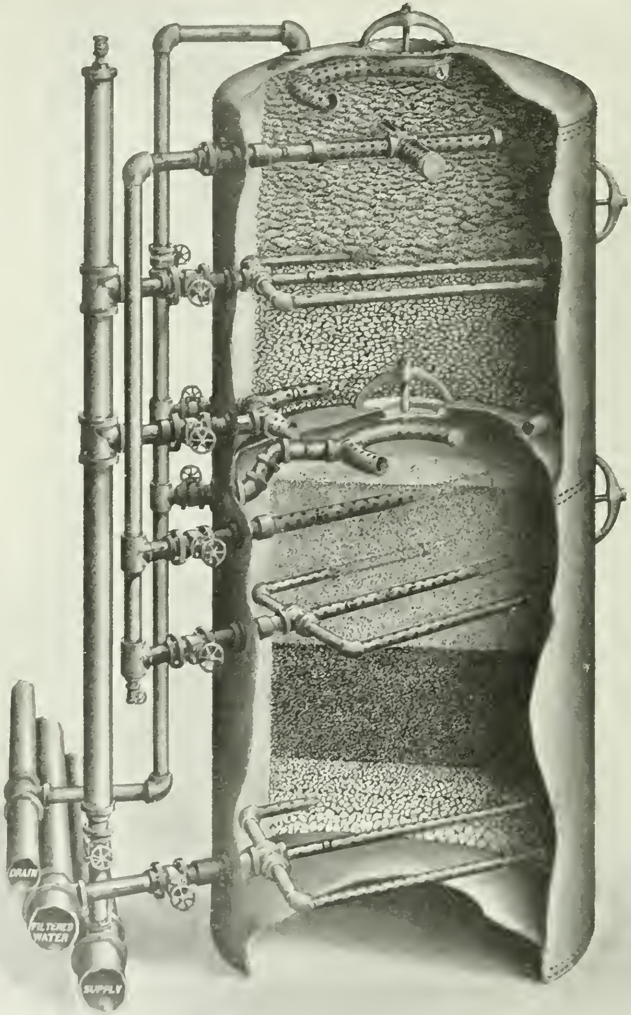

Fig. 8
Tripple Filter in City Hall, Phila.

filtration added to the old processes and not likely to cost a twentieth part of a new supply, can easily take care of the little excess, if any, of organic matter traceable to the canal.

# EDWARD LANGFORTH ADAMS.

## IN MEMORIAM.

In the death of Mr. Edward Langforth Adams the Western Society of Engineers lost a young member who was a typical American; who, had his life been spared, would have taken a high stand in the engineering profession and been a credit to the Society.

Mr. Adams was born in Philadelphia in 1875, and took the course in Mechanical Engineering at the University of Illinois, graduating with the honors of his class in 1896. He was entitled to a scholarship prize of $500, which he generously resigned in favor of a young man who was next to him, but "who needed the money more than I did."

In the fall of 1896, young Adams became attached to the office force of the late David L. Barnes, with whom he continued until Mr. Barnes died in 1897. It has been said of Barnes that he was a pretty hard master, very exacting in his requirements, and that the young man who could remain any length of time in his office had to be a good one and a hustler. Adams passed the ordeal and won the regard and approval of Mr. Barnes, who was heard to say that "Adams was bound to make his mark some day."

Accepting a position as draftsman and inspector for The Sargent Co., Mr. Adams became closely identified with the iron and steel foundry business, and was from time to time promoted, occupying the positions of mechanical engineer, assistant superintendent, superintendent of the Open Hearth Department, and at the time of his death was assistant to the President, in full charge of all the mechanical matters pertaining to the operation of the works in Chicago and at Chicago Heights. Mr. Adams was an energetic worker, of slim build and nervous temperament. He gave no regard to personal comfort and never hung back, seldom questioning his orders, but with a short "Yes, sir," he received his instructions and carried them out to the letter.

A close student, he combined theory with practice and was rapidly developing and broadening out into an engineer well posted in the metallurgy of iron and steel, and in the economies of shop operation so necessary for the successful manufacturer.

Mr. Adams was sent to England to investigate certain foundry practices, and while there made many friends who commented upon the intelligence and youthfulness of the young engineer. He made a good impression wherever he went, for he was not only a very bright young man, a student as well as a practical worker, but throughout his varied experiences was always a gentleman; clean, honest and upright, exciting attention by his gentleness as well as by his evident abilities.

In December last, at Christmas time, a fire occurred, disabling the machinery operating the Tropenas steel casting plant of The Sargent Co., at Chicago Heights. By working continuously all through Christmas day and night, Adams, with his force, got things into shape to resume operations without loss of time; but the exposure to the extreme cold weather brought on a cold, which developed into pneumonia, and after a very brave fight he died on the morning of January 31, 1902, at the age of 27 years.

The funeral took place from his home in Austin, Ill., February 2, and was attended by a large force of his business associates, ranging from the President of the company down to the humblest shop man, many of whom had come a long distance in very cold weather to bear witness to their affection to the young man and sympathy for the family; for Adams after all was really a home boy, clinging close to his parents and reflecting in his life their gentleness and strong character.

Chicago, Ill., Feb. 8, 1902.

F. W. Sargent,
J. C. Whitridge.

## ABSTRACT OF MINUTES OF THE SOCIETY.

### ANNUAL MEETING, JANUARY 7, 1902.

The 461st meeting of the Western Society of Engineers, being the thirty-second annual meeting, convened in the parlors of the Auditorium Hotel about 7 P. M., January 7th, 1902, with President Chanute in the chair, and about 100 members and guests present.

The reading of the minutes and of the several reports of the Secretary, Treasurer, Auditing Committee, Library Committee, Publication Committee, and the Paris Exposition Committee, on motion, were dispensed with. The Secretary, however, at the request of President Chanute, read the report of the Judges of the Election, as follows:

JANUARY 7, 1902.

*To the Western Society of Engineers:*

We, the undersigned, Judges of Election, have canvassed the ballots for officers of the Society for the year 1902, and have the honor to report as follows:

| | |
|---|---|
| Total number of ballots received | 208 |
| Total number of ballots rejected | 60 |
| Total number of ballots accepted | 148 |
| For President, W. H. Finley received | 147 |
| For President, G. A. M. Liljencrantz received | 1 |
| For First Vice President, Ralph Modjeski received | 146 |
| For First Vice President, Garrett Davis received | 1 |
| For First Vice President. Geo. P. Nichols received | 1 |
| For Second Vice President, L. P. Breckenridge received | 86 |
| For Second Vice President, T. W. Snow received | 61 |
| For Treasurer, J. C. Whitridge received | 147 |
| For Treasurer, T. W. Snow received | 1 |
| For Trustee, J. W. Alvord received | 148 |

Yours respectfully,

WILLIAM S. LOVE,
BYRON B. CARTER,
G. F. BECKERLEY.
Judges of Election.

President Chanute then made the announcement that Mr. W. H. Finley would be the next President; Mr. Ralph Modjeski would be the First Vice President; Prof. L. P. Breckenridge would be the Second Vice President; Mr. J. C. Whitridge would be the Treasurer; and Mr. J. W. Alvord would be Trustee for three years.

On motion, the report of the Board of Direction was postponed until after the annual dinner had been eaten, and the Society and its guests adjourned to the banquet room of the Auditorium.

At the conclusion of the dinner President Chanute called the meeting to order and asked the Secretary to read the report of the Board of Direction as follows:

### REPORT OF THE BOARD OF DIRECTION.

During the year 1901 the Society enjoyed its share of the general prosperity that prevailed the country over.

Our membership has increased about 11 per cent; the present membership being 558—a gain of 56 over the preceding year. Eighty-three new members have been elected. In addition to these, 13 applications have been favorably acted upon by the Board, and of those, more than half have since qualified. Death visited our ranks during the past year and called 8 members of the Society to join the great majority.

The Society is in a flourishing condition financially. Attention is called to the Treasurer's report. This report gives the receipts for 12 months, and disbursements for 13 months. The Board of Direction approved, on December 31st, the accounts that are usually paid in January. This was made possible by the fact that we had sufficient funds in the treasury to do so without drawing on the $2,000 in the form of time certificates. The receipts for the year amounted to $8,995.40, and the expenditures for the same period amounted to $8,607.45, leaving a balance of $387.95 against a balance of $51.44 for the preceding year. Full detailed statements of the receipts and expenditures will be found in the report of the Secretary and Treasurer, hereto appended.

There have been 24 meetings held during the past year. This includes the annual meeting at the Grand Pacific hotel, and one meeting held in the Art Institute. It also includes two "Smokers" held in the Society rooms.

Thirty papers have been read before the Society during the year. A list of these papers, with the authors, will be found in the report of the Secretary.

The accessions to the library during the year amounted to 352. The total number of volumes in the library at present time amounts to 3,975. Our exchange list now numbers 195 publications—an increase of 15 over last year.

The various officers and committees have discharged their duties in a very satisfactory manner.

The Publication Committee is deserving of great praise for the efficient manner in which it has conducted the JOURNAL.

Through the generosity of one of our members, the Society has been enabled to offer prizes for the best papers on Civil, Electrical and Mechanical Engineering. The awards were made by the Board, as follows:

Mechanical Engineering,—"A Simple Method of Determining the Conditions of Combustion, with Suggestions on Working Furnaces," by A. Bement.

Electrical Engineering,—"Electrical Oscillations of High Frequency," by A. V. Abbott.

Civil Engineering,—"The Water Works System of Chicago," by J. H. Spengler.

"Coefficient of Expansion of Concrete," by Prof. W. D. Pence. The latter being a supplemental medal, which the Board thought well to award.

The Board found the present method of book-keeping unsatisfactory. It had adhered to it in order not to make a change in the middle of the year, but recommends that the incoming Board shall adopt improved methods at once.

After the presentation of the report of the Board of Direction, the retiring president—Mr. Octave Chanute—presented his report, which is printed in another part of this JOURNAL, and in conclusion said:

Now, Mr. President-elect, I am going to hand you this gavel, which was handed to me by my predecessor, and which I have used so carefully that I have only used it on one occasion, and that is tonight. The members, you will find, are so good, so orderly, that there is very little occasion for a gavel, and it will wear a long time.

To which President-elect Finley replied, as follows:

Gentlemen, I am sensible of the honor you have conferred upon me by electing me your President. I wish to thank you for the high compliment, and to bespeak your co-operation in making the Society as much of a success in the coming year as it has been in the past. If there is any one feature more than another that contributes towards the success of the Society, it is our JOURNAL, and I think we should receive from every member his earnest efforts towards making the JOURNAL a success.

In listening to the retiring president's address, I felt that "a free confession is good for the soul," when he admitted he was opposed to the Society withdrawing from the Associated Societies and publishing a journal of its own, and now acknowledging that he was wrong. The only way we can continue to make the JOURNAL a success is through the help and efforts of the members, and I earnestly request you to help us out all you can in making the JOURNAL a success for the coming year.

In this connection, there has been placed in my hands a communication, which I will now read

*Mr. W. H. Finley, President Western Society of Engineers, Chicago, Ill.*

DEAR SIR:—Enclosed I hand you a certified check for $1,000, to constitute an endowment in the name of the Western Society of Engineers, the revenue therefrom to be applied in awards of prizes for papers read before the Society, under such conditions as the Board of Direction may determine.

(Calls for name of the donor.)

*The Chairman*—It is a very unfortunate thing that I should forget the name. I was so elated over the check that I forgot everything else.

(Signed) Yours truly, OCTAVE CHANUTE.

*Mr. Condron*—Mr. President and Gentlemen: I am sure we are all deeply grateful for this generous act on the part of our retiring president, and the full appreciation of what it means can hardly be realized by us in an instant. It not only means that he has made an enduring name for himself in the Society, but that he has immeasurably benefitted the Society, by making it possible for annual prizes to be offered for meritorious papers read before the Society. Having been on the Publication Committee myself, I believe I can somewhat appreciate what this means. I therefore feel that we should make some acknowledgment in this meeting tonight of Mr. Chanute's generous act, and I, therefore, move that a suitable resolution—which I hardly hope to appropriately word now—be adopted, tendering to Mr. Chanute, the thanks of the Society for his generous act, and also requesting the Board of Direction to accept this gift, and thereby to establish a prize to be known as the "Octave Chanute Prize."

*Mr. Liljencrantz*—Mr. President, I wish to second that motion.

*The Chairman*—It has been moved and seconded that a vote of thanks be tendered to Mr. Chanute for his generosity, and also that the prize be known as the "Octave Chanute Prize."

The motion was carried unanimously.

*The Chairman*—Gentlemen, it is my earnest hope that, when I come to lay down the cares of this office, I shall have discharged the duties of it to your satisfaction, as completely as my predecessor.

In this connection, we have read very frequently of "I regret to report," and I regret that I am compelled "to regret" tonight, but the fact is that the Toastmaster selected for this evening, Mr. Willard Smith, is unable to be with us, on account of illness, and you will be compelled to submit to me for the rest of the evening.

The first speaker of the evening is Mr. N. H. Stewart, of Michigan, who will address us on "The Right of Way."

*Mr. Stewart*—Mr. Chairman and Gentlemen: I think it is hardly fair to call on an outsider to break the ice in the speech making before so elegant a body of gentlemen.

I am a lawyer, not an engineer, but I have come in contact, all my life, with members of your profession, as I am one of the attorneys of the Michigan Central, as well as a local attorney for the Chicago & Grand Trunk, and it has always been my delight to meet with Civil Engineers, and I have found in that contact, upon all occasions, that they were men of high standing, fine literary attainments, and *gentlemen*. I never, in all my life, found men more so. And yet why should they not be such? They belong to a profession as old as any historic record that may be found. The history that we have of the rise and fall of the various nations cannot give us the birth of the society of engineers, and of Civil Engineers especially. Their works tell the story that they existed before the recording of the history that has come down to us today, not even excepting the great pyramids along the Nile and in Egypt. Those were built by the Civil Engineer, and so perfect was their work done then and in that day, that the variation of the magnetic needle may be determined by the perfect sides of those great monuments. They have stood there not only as monuments of Egypt's grandeur, but of the grandeur of the profession of engineers

This subject of "The Right of Way" is one as broad as space, and anyone has the right to use it as he pleases, so long as he does not interfere with or injure his neighbor or anybody else.

I do not propose, being the first speaker before you this evening, to take up your time and tire you with subjects that you know more about than I do. I am here in the first place, through the invitation of my very dear friend, Charles W. Hotchkiss, who, I regret, (as well as some of you), is absent. And I have received a telegram from him that I must represent him on this occasion, so if I make some mistakes I will charge it up to my friend Charles, and you must blame him for it. But he says any old thing will go. You are tired and you don't want technical subjects talked about here and I don't propose to talk about them.

There are many "Rights of Way," not only across the earth, but intellectually, and the man who first gets them is entitled to them just as long as he can maintain them, and no longer. He is opposed on every hand, and when that opposition is strong enough to displace him, he goes. So he should prepare at the start for switches and side-tracks, to get out of the way and not get hurt.

But I understand, gentlemen, that this is a time for merry making. You are all men who work intellectually, as well as physically. You get tired of your levels, and rods, and lines, and you have met together here for merriment, and I am called to join you. It is a time, it seems to me, when the night should be filled with music, and the cares which infest the day should fold their tents, like the Arabs, and silently steal away. And I do not propose to prolong any agony here by the discussion of any subject about which, as I said before, you know more about than I do, and I want, so far as I am concerned, to remember this night tomorrow, and tomorrow, and tomorrow, until the last toll of the bell and can turn back and say:

"I ha'e been blithe with comrades dear,
I ha'e been merry drinkin';
I ha'e been joyfu' gathering gear,
I ha'e been happy thinkin'"

"But of a' the pleasures e'er I saw,
Though three times deeply, fairly,
That happy night was worth them a',
Among my friends sa dearly."

That is the way I feel tonight, gentlemen, and as I represent Mr. Hotchkiss, and as he tells me that some of the members that used to belong this Society are no more, he wished that I should propose a toast to him and the absent ones, and I propose to do so and to tire you no longer, gentlemen, after I have given you this toast:

"Here's to our brothers who have gone before,
Through the portal to that echoless shore;
What is their lot no one can tell;
We drink to their health and we wish them well.

Here's to our brothers on land and sea,
Absent from home, wheresoe'er they be;
Whether on mountain or plain or in dell,
We drink to their health and wish them well.

Here's to our brothers in fortune's smile,
Whose hearts beat happy all the while;
May the sunshine of life with you ever dwell,
We drink to your health and wish you well.

Here's to our brothers on beds of pain,
Whose hearts are sorrowful with but little gain,
May the sunshine break through and with you dwell,
We drink to your health and wish you well.

Here's to our brothers with hearts bowed low,
Laden with sorrows, with cares and woe;
May the angel of mercy break the dark spell,
We drink to your health and wish you well.

Here's to our brothers around this board,
Whose hearts beat in sympathy with one accord;
May we in the future of this love-feast tell,
We drink to your health and wish you well."

*The Chairman*—Gentlemen, we now know what "The Right of Way" is. Those of us at least who are engaged with railroads always supposed it represented a hundred feet strip of earth. It does not represent anything of the sort, it is not bounded by the universe!

The work of engineers has been very freely criticised and abused from an architectural standpoint, and for that reason we have selected for the next subject on the programme "The Æsthetics of Engineering." Doctor Gunsaulus hardly needs any introduction to a Chicago audience.

### "THE ÆSTHETICS OF ENGINEERING."

*Doctor Gunsaulus*—Mr. President and Gentlemen: I have wondered very much tonight if there is one among us here who, in spite of the lucid information which we have received on "the right of way," has any conception how much is left of the right way for a man, who, interested as we are in the good cheer which we all endorse and which we all so thoroughly enjoy, confronts educational questions.

I want, in the first place, to bring to you tonight the hearty gratitude and the daughterly respect of the Armour Institute of Technology. This institution was born of the spirit felt at this assembly. There is no association in this country at the present time that, in my judgment, means so much for the future of educational engineering or engineering education, in the Central West, as the Society which I have the honor to address at this time. The right of way is what true education gives to a man. This right of way is, as our friend has told us most eloquently, broader than space, and it is longer than time. It reaches far out to the very limits of humanity, and has to do with the progress of our race on this planet.

In the making of the Armour Institute of Technology we have tried to see how clearly these great edges of thought and action come towards one another, and at last mingle with one another, until it is possible tonight for me to be invited here to speak just a word on "The Æsthetics of Engineering." When Mr. Armour first looked into this problem in the Central West, to see and judge the future before man, as he was dealing with the problems of life and time, I think he had something more than the vision of a mere business man. He saw that the engineer, wherever he is, in whatever realm of life he may have his tasks, is the man of the future, and is the only kingly being in the presence of the forces and facts and possibilities of our America. He is the only man into whose hand, naturally and inevitably, the supreme energies come, and he is the only man who is likely to use them with that complete vision which every soul has who seizes hold of the best things for humanity.

And so it occurs that tonight a society which was once organized around the idea that civil engineering was about the only sort of scholarly or practical engineering—when this great plain here was a swamp near the lake, when all these railroads had to be builded and when these bridges had to be arranged for, asks for engineers of many other sorts to complete its life. We consider this, inspired as we are by the words and presence of one whom we all revere, the honored retired officer of this club, who has been pleading for the association as those other realms of engineering that are just as certain to control the future, along with civil engineering, as the newly acquired realms of scholarship in any great world of thought are sure to associate themselves for the higher achievements of the human mind.

Here, for example, is chemical engineering, occupying a place in our hope which electrical engineering occupied twelve years ago. We are amazed at all the wonders which come to us by the discovery of practical uses for our chemistry, and we are glad to find that all the marvels which have come to us through the study of chemistry will yield business results at the command of the engineer. Much also comes through our study of physics, and by that metaphysics which is deeper and higher and stronger than physics itself. It is all the engineer's new world. As I said, here is chemical engineering, claiming at last to deal with the wastes of our modern society, to deal with the dumps of our coal mines and our silver mines, to take just what we thought was wasted and to make out of what is a burden and a blunder in the track of man something highly successful, something which he shall enjoy, something which shall add to the treasures of mankind, and therefore it has its æsthetic spirit and aspect

So in this comparatively new science of chemical engineering it becomes very much more clear, and in the science of electrical engineering and in the science of mechanical engineering, and how especially clear the æsthetic feature is when we see that all these forces in engineering are permanent forces toward making this a more beautiful world.

Here I am invited to-night, by the grace and kindness of this association, to speak to you in spite of the fact that I am a minister of the Gospel, but I am a kind of a spiritual engineer, if I am doing anything at all in my profession. Not a solitary rule, not a single maxim, not any equation of your profession but that can be turned over into its spiritual equivalent in my profession. There is not a single railroad well builded in this country that does not hold spiritual lessons for the man who is seeking to lead men out of Egypt toward Canaan. There is not a bridge over any difficult stream, there is not a track or cable by which bodies can be transported from one place to another that has not its expression in that higher life, or, as we call it, the spiritual life. And so we see that the engineering profession has not only its æsthetics, but has its ethics as well.

In all your work you have to deal with truth. Some day we will so clearly see into the practical affairs of life that we will confess that there are just three phases of all true education and all true power. There is truth, there is beauty, there is utility. The preacher comes to you with truth, whether he be a preacher in this realm or not, and he says to you that truth is the intellectual side of morality. And so a man comes to you and he sees your bridge in its complexity and its ability to resist, and if it is a really true bridge, it comes to be, in the very highest sense, a beautiful bridge, and if it is a true bridge it is also a useful bridge. So that, here is the realm of ethics, æsthetics and technics so united in one thing that it is entirely impossible to get a great engineer until you first get a really great man. Never has there been any great work in the history of your science or art but that has come out of the depths of some great mind. It is the expression of some manly spirit. It is useful because it is true, and when it is most true and most useful it is most beautiful, and the ethics and æsthetics of the engineering profession are just as much a part of the great literature of the human soul as Shakespeare's poems, as the art of Phidias or Michael Angelo. The world then, before it will ever be a true world, the world of railroads, the world of steam engines, the world of drainage canals, must be a useful world, and it never can have its highest use until it is a beautiful world. Chicago herself, with her problematic river, with her billboards and everlasting nuisances and noises is not only an engineering problem, it is a problem in moral and artistic engineering, because it is the problem of every true man, and the man of Chicago must first call upon his engineer to make Chicago a truthful city and a useful city before she can ever become a beautiful city.

And who are the poets of the 19th century, who are the men that are to write the epics of our time? Your compeers are the spirits that have created the great lyrics that move upon wheels, that make life worth living, that add to the splendor and glory of man's career here below.

I congratulate you upon your profession, and I wish you well forever.

*The Chairman*—Gentlemen, one of the necessary adjuncts of an engineer is a library, and a technical library above all others. I will next call upon Mr. Andrews to respond to the toast "Technical Libraries."

"TECHNICAL LIBRARIES."

*Mr. C. W. Andrews*—Mr. President and Gentlemen: When I was first asked to speak upon the subject of Technical Libraries I rather demurred, as I have spoken so often on the one particular library that I know something about, and in which I am most interested. But I thought I might take a leaf from my brother's book. In the old school at Boston it was Declamation Day. The first boy rose to declaim the poem he had chosen—"The Charge of the Light Brigade"—and began, "Half a league half a league, half a league onward." It was one that had been often spoken, but there was a new teacher! The next boy happened to have selected the same piece, and he began, "Half a league, half a league, half a league onward." Then it was my brother's turn, and to make the coincidence still more marked he had selected the same piece, but fearing the effect upon the teacher he introduced an element of variety. He began, "A *league*, a *league*, a *league* onward into the valley of death rode the six hundred." It was a bright class, and a hint was sufficient. The next boy began, "A league and a half, a league and a half, a league and a half onward." The rest of the story has very little relation to the point, but for the sake of those whose curiosity may be aroused, I might say that the class got it up to three and one-half leagues before the teacher called a halt. He said that he would like to know, as a matter of curiosity, how many of the rest of the class had expected to speak "The Charge of the Light Brigade." They all raised their hands. As I said, that latter has very little to do with the point that I wished to make, which is, that in respect to the only technical library I feel at all capable of talking about, I can only introduce my brother's variety and make a report of progress since I spoke last upon this subject.

It seems to me that the last year has seen one of the most important steps in the library situation in the United States. The Library of Congress has finally decided that it will take the place which it should take as the leader of American libraries, and will attempt to do the things which only that library can best do, and give us the benefit by those labors, and leave to us the time and resources for the needs of the individual library.

You have already heard of the progress made by your own library, and I congratulate you most heartily on the results. A technical library is certainly a necessity for such a body of men. However, it is not of your own library, but of the union of city libraries that I wish to speak this evening.

The fifteen public libraries of Chicago and Evanston have united in publishing a joint list of their sets of serials, and it seems to me that the accomplishment of this, as well as the spirit which lay behind the forming of the union, should aid in the advancement of the Chicago libraries. I hope this may go on, and that the co-operation may become more intimate. We shall find that we can help each other, as we shall find that the Library of Congress will help us all.

Turning now to one library—the one which I have the honor to represent—we have not been standing still. I think we have gone half a league further. During the past year the library has added some 11,000 volumes to its books, making 76,000 in all. It has seen the attendance increase 31 per cent., and the use of books 34 per cent.

During the year it has taken the first steps towards securing a site for its permanent building, and has prepared sketch plans which seem to promise an attractive and useful, as well as a monumental building. I am sure that I speak to well-wishers of the library who will certainly feel that it will do its best service in the central portion of the city, and that the plans are none too large for the needs of the city in the direction of a collection of technical books.

Now, as to the subject of engineering in particular, I would remind you that we have tried to get those books which the individual engineer is not able to have—the books which the "Western Society" even, is not able to secure promptly and in large numbers. I would say that we have added, in engineering and electricity this last year, more than 1,500 volumes, and the collection now numbers over 7,500 volumes. The periodicals are in a similar proportion, and the reading of both books and periodicals is in even greater proportion to the total number of readers. Engineering is the largest single subject in number of volumes, and it is the largest single subject in the number of books read.

It is with this report of progress that I would call the library to the attention of your new members, and give them the same welcome that I have before given to you all, to come and visit us and make use of the library at all times. If you are married, the best way to find it will be to ask your wife where the lunch room of Marshall Field's is, and she will be pretty sure to know that. But please do not, when you come up to visit us, remark as you come in, "Is this the department where they sell books?" because we do feel rather hurt in being classed as a department of the store. Perhaps it might be just as well not to remark how very kind Marshall Field & Company are to fit up such a beautiful reading room for their employees. Of course the advantage of being connected with so distinguished an establishment is great, but at the same time it has some disadvantages.

And I shall close, gentlemen, by repeating the welcome extended to you, and ask that you will let me know when you come, and I will help you, as far as I can, to make you feel entirely at home.

*A Member*—I would like to ask the gentleman who has just spoke how the members who are not married will find where the library is?

*Mr. Andrews*—You would better get married, young man.

*The Chairman*—Gentlemen, I hope you will take advantage of Mr. Andrews' kind invitation to avail yourselves of the library.

The Western Society of Engineers meets about twice a month and read papers, and might be considered as holding a sort of mutual admiration society, but tonight we are in a position to realize the wish of the poet, Burns, when he says:

> "Oh, wad some power the giftie gie' us;
> To see ourselves as ithers see us."

Gentlemen, I take great pleasure in introducing our guest, Mr. P. Glasenapp, Engineer-Attaché of the Imperial German Embassy at Washington.

### Address of Mr. P. Glasenapp.

Mr. President and Gentlemen: Permit me to express in a few words my warmest thanks for your cordial invitation to your annual meeting, and especially let me thank you, Mr. President, for your very great amiability in offering me the use of the privileges of your Society during my presence in this city.

I feel very glad that I, today, have the opportunity to acknowledge my appreciation to the American Engineers of all the favors which they have bestowed upon me wherever I have been during my stay in this country, and I only hope that we German Engineers may have the opportunity to return these many kindnesses.

It is with much interest and great admiration that I have observed and studied the many great works of American Engineers. In all departments, the water works and water ways, the bridge building, the railways, and not least, the steel works, the machinery and works of electricity; there is a great amount of wonderful and marvelous work.

This extensive and rich country, with its valuable resources, gives many problems to solve, many great tasks to perform, and the American Engineers have shown to the world that they are capable of performing these wonders. Not only have they mastered these tasks but they have often done it classically.

Not the least factor in this are your clubs and associations, which are of the highest possible standard. The many valuable proceedings and annual reports are witness to the intelligent and diligent work that is done in your clubs and societies.

It is also upon such successful and scientific work that I wish to congratulate the Western Society of Engineers, and I do this in my German manner, by lifting my glass to a *vivat, floriat, crescat* of the Western Society of Engineers.

*The Chairman*—Gentlemen, our retiring president has told us something of the early struggles of the Society, and I will now call upon Mr. Morehouse to respond to the toast, "The Peregrinations of the Society."

### "The Peregrinations of the Society"—Address of Mr. L. P. Morehouse.

Mr. Chairman and Gentlemen—I cannot say that it is with unalloyed pleasure that I stand before you, because it is a moment of trepidation to address an audience like this, but I cannot refrain from saying that it is a pleasure to stand here.

As our friend, Mr. Chanute, tonight recited some incidents in the early history and progress of the Society, and I heard my name mentioned from time to time, I recalled that there is a gentleman in the city here, whose name you see occasionally in the newspapers, a middle aged gentleman, or perhaps an elderly gentleman you might say, certainly a very well preserved gentleman, whom I meet occasionally, and incidentally he refers to Chicago in the 30's, and getting to more recent times to the 40's, perhaps, and as my name was mentioned tonight so frequently, I began to think that hereafter I might say "Me and Fernando Jones."

But I have a very easy task before me, something like the recitation of the multiplication table, to give a statement of the different quarters, or rooms, or buildings which the Society has occupied from its infancy up to the present time. I would like to be poetic upon the subject, but unfortunately my talent is not in that direction I have had more to do with prose than poetry. I did write poetry at one time, to amuse myself, but when I found that the world was not thirsting for my poetry I did not care to force it upon the world, and for many years I have refrained from exercising that latent talent. And so, my poetic powers lying dormant all these years, I am unable to paint in poetry, scenes which I should like to paint in the history of the localities which the Society has occupied from time to time.

As has been stated upon more than one occasion, I will repeat that our first meeting as an organization, The Civil Engineers' Club of the Northwest, was by invitation, at the office of Colonel Mason, on the corner of Lake and Dearborn streets, where a number of gentlemen met, as Mr. Chanute has recited tonight, and the Association was organized. We met there for several meetings, and then, on the 9th of August, 1869, we began to hold meetings at the Sherman House, the use of the club room of that building having been very generously tendered to us by Mr. Irving Pearce, who has so long been the genial proprietor of that hotel. We continued to meet in the Sherman House until the fire of 1871, in October, destroyed that building, along with many others in the City of Chicago, and we were without a home. But on the 20th of November we met again. The Sherman House had not risen from its ashes, materially, but it had risen nominally as the New Sherman House, and was located in a building on the West Side, either at Randolph or Madison street, I cannot recall at this moment the exact location, but we met under the auspices and enjoying the hospitality of the Sherman House.

We met there until December, 1872, and then being somewhat dissatisfied with the locality, and being desirous of affilating ourselves with a kindred organization, we accepted an invitation from the Chicago Academy of Sciences to hold our meetings in its building, or rather in the rooms which that society was occupying at that time, on Wabash avenue.

I think that, on a previous occasion, I read the minutes of the meeting which was held at the Chicago Academy of Sciences on that occasion, when the members who endeavored to be present at the meeting were unable to find any such location and were obliged to take refuge in a convenient doorway, which some commentator has suggested or intimated or stated was the door of a saloon. I don't know how such knowledge was obtained, there is nothing of record that I can find in the minutes of the Society, and I think no official statement has ever been made to that effect, but I find it a sort of a belief among the members of the Society, the younger members who heard this suggestion, that there was the door of a saloon. I will simply say, gentlemen, there is nothing official that warrants any such statement.

That meeting at the rooms of the Academy of Sciences was the last one held in those quarters, for in the month of February I find that we were meeting in the office of Mr. Chesbrough, at that time city engineer, and the city offices at that time were in what began to be known, shortly after that, as The Rookery, a building originally erected in connection with the city water works. It was one of the tanks, one of the distributing reservoirs, three of which were erected in 1852, or about that time, in connection with the city water works. It had been out of use for many years as a water tank, but the city, after the fire of 1871, took possession of it as an office building, and built around it a low two-story brick building, furnishing other offices for the accommodation of the city officials, and at that time the locality, or the collection of buildings, was known as "The Tank."

Here in "The Tank," or the Rookery, as you may please to call it, we remained until September. Then we returned to our first love—that is, our love of that character—the Academy of Sciences, and accepted the invitation of that society to occupy its rooms on Wabash avenue, and there, in the congenial society of megatheriums, mastodons and fossils of the pre-historic ages, we assembled for about a year, until September, 1874, when we made arrangements with the Chicago Chapter of the American Institute of Architects. That society had rooms at 145 Clark street, and that was the first time in the history of the Society when we paid rent for our rooms and felt that we were independent of the hospitality of other people. This room was in the fourth story of the building. There were no elevators in those days: people were good walkers, and we had a very pleasant time, I remember, in those rooms. But it seems they were not entirely satisfactory, perhaps they were a little inaccessible, for I find that the year after, in September, 1875, we returned to our very first love, the Sherman House, which had been offered to us again. Mr. Pearce was always very desirous that we should come and avail ourselves of the privileges of his house. There we remained until June, 1878, when we took a vacation, as we were in the habit of doing in those days—holding no meetings during the summer months.

While we were in the Sherman House we were, of course, under obligations to our host, to whom we paid no money, so at the end of every year we were in the habit of ordering a collation, to be served by the Sherman House to the members of the Society, and those were the beginning of meetings of this character. The Society always provided the repast, without expense to members, a custom which has been discontinued at the present time. There were some advantages in belonging to the Society in those days, you see. And so, in that way, we discharged our obligations to the Sherman House.

In 1878, in September, feeling that we ought to have rooms that we could call our own, we made arrangements with the Chicago Atheneum, which at that time occupied the building at 50 Dearborn street. The Atheneum was then and is now one of our educational instiutions in the city, with which most of us are familiar. At that time it was not conducted on quite as extensive lines as at present, but it occupied that building for a long time, and while we held our meeting in one room we could hear the French teacher in an adjoining room, laying down French to his scholars, and the music teacher in another room expounding the piano, and the music teacher above wrestling with the violin. So we not only had the benefit of our own proceedings, but of the united instructions of the Atheneum.

We accepted the hospitality of the Atheneum—we were not above those things in those days—until January, 1880, when we made another move. The music, and French, and Spanish, and the like were a little objectionable, and we thought we would have a more quiet spot, so we accepted the hospitality of the Western Railroad Association—we always had a great many friends, gentlemen—which had very commodious rooms in the Honore building, rooms which were occupied once a month by the Board of Directors,—two large rooms—but during the remainder of the month were occupied only the Secretary and his small clerical force, so that we had very comfortable and pleasant rooms in connection with that association, until December, 1883, when we decided to make a radical change, to hire rooms which should be exclusively our own, and to furnish them. We, therefore, hired a very good sized room in the American Express Company's building, on Monroe street. A number of our members contributed for the furnishing of the room, we obtained whatever was necessary, and we had quite an attractive room, which was more or less—rather less—used, during the time for which we hired it. Because, I think it was during that period that we fell into this condition which Mr. Chanute has referred to, when it was necessary to go out into the highways and by-ways to compel people to come in. For some reason there was a very great lack of interest in the Society. We were obliged to advertise that there would be a lunch and all the members were requested to be present, but, notwithstanding the cases of beer that appeared, and the sandwiches and other concomitants, our attendance was largely made up of newspaper reporters, and after a while we concluded that, however valuable the press might be for the dissemination of knowledge and information, it was hardly the province of the Society to set out a monthly lunch for the press of Chicago. So we stopped giving the collations, and after a while we gave up our rooms there.

I think we were in a rather bad financial condition at that time, and so we made an arrangement with an association composed of the architects and contractors of the city, under the name of the "Permanent Exhibit of Building Materials." Many of you, doubtless, recall the organization. It occupied one floor of the large building on the corner of Wabash avenue and Washington street, and one corner of that was fitted up as a meeting room and made a very comfortable place for our meetings and the meetings of the Architect's Society, which also held its meetings there—and I think one or two other organizations.

We remained there—this is very interesting, gentlemen, I don't see anybody asleep yet, but I had expected it before this—we remained there until May, 1888, when we moved from the "Permanent Exhibit of Building Materials" to the society exclusively of the people who have to do with building materials, the Chicago Chapter of the American Architects, again, at No. 67 Washington street, where we remained until April 1889. In 1889, one year after that, on the 1st of May, we moved again. We got into the habit of moving, you see, and that being a Chicago habit, it is contagious; we felt that we had to move, so we moved to 78 LaSalle street, where we had very comfortable quarters, as I remember them, directly opposite the City Hall, and there we remained for five years. So that you see we were pretty well satisfied with our quarters at that time.

But in 1894 we moved to the Lakeside building, where we had a reading room, and a library, and a store room, but we did not have a good room for holding our meetings, and at that time we held the monthly meetings of the Society at the Grand Pacific hotel, in the club room of that building.

In January, 1895, we occupied our present quarters, in the Monadnock block, and we seem to have been fairly well satisfied with these, and we have made no change since 1895, except to enlarge the quarters.

It is only proper to state that during these last few years we have been frequently indebted to the hospitality of different societies or bodies for the places of our meetings, and especially we have been indebted to the Armour Institute, whose rooms were tendered us to be used as often as we cared to use them, and as a matter of fact, during two years, at least, we held very frequent meetings at the Armour Institute.

During the course of our peregrinations we have held special meetings at many places; we have held meetings on steamboats, cruising in Lake Michigan up and down in front of the city; we held an annual meeting down in South Chicago, in an unfinished rolling mill, where the members distributed themselves around on different pieces of machinery that were waiting to be placed in position; but wherever we were we transacted our business in harmony and with satisfaction to ourselves, and presumably to the rest of the world.

But I would add one word which I cannot refrain from at this time, and that is that in all these years of my connection with the Society and my association with the different members, many of whom I have known so well, it has been one of the great pleasures of my life to see not only the physical works which many of these gentlemen have superintended or carried out, the works which will remain after they have passed away, but to have associated with these gentlemen who have built up themselves as enduring monuments of personal character; who have made a record in their personal lives, and placed before the commnnity the evidence that engineers can make, not only monuments of stone and of metal that shall endure, but shall make, can make, do make, character for themselves, the remembrance of which will not be forgotten by their friends or by any community in which they may live.

*The Chairman*—After listening to Mr. Morehouse's statement of the early struggles of the Society, and the various moves we have made, I think we ought to all make a resolve that our next move would be into a permanent building of our own. We have listened to talks on engineering subjects and matters pertaining to engineering. The next number on the programme is one that is redolent of magnolia groves. I will call upon our Past President, Mr. Isham Randolph, to respond to the toast "Old Virginia."

## "OLD VIRGINIA."

*Mr. Randolph*—Gentlemen: Some days ago I was called up by a member of the Entertainment Committee and told that I was to come here tonight prepared to talk, and he said I could talk about anything I pleased, just so long as I did not talk shop.

You may remember that some years ago I produced the results of an old poetry machine that I brought with me from Virginia many years ago, and after that I used that same poetry machine when Dewey was here. The results were quite widely commented upon, and I will give you one comment. I think this was taken from a Duluth paper:

"The Chief Engineer of the Sanitary District has written a poem commemorative of the visit of Admiral Dewey. Those who have read the poem say that he may be a good civil engineer!"

Well, when I was called upon for this occasion I concealed that old machine about my person, and whenever nobody was looking I turned the crank a little bit and ground out a little bit, and I had gotten along pretty well with it when I received a note from the Secretary of this organization telling me that the Board of Direction desired me to speak upon "Old Virginia." I put that note into the hopper, and the tenor of what the machine had been doing before was changed :

The Hello Girl had finished,
  Then another voice I heard,
And I knew the man behind it
  When he'd said the second word.

I couldn't see the owner,
  For he was so far away,
But I marked with strict attention,
  Each word he had to say.

He spoke of sounding "Bubbly Creek,"
  I thought he'd like to know
What made the District Engineer
  So everlasting—slow.

I made a mild apology,
  Through him, to Uncle Sam,
Who wished to know the reason why
  Those river men say dam.

A very ugly word, you know,
  For river men to use,
They should in language less profane
  Express their pent-up views.

But sailor men are seldom slack
  In using cuss words torrid,
And nothing said of Bubbly Creek
  Would be at all too horrid.

He did his part by Uncle Sam,
  Then talked of other plans,
And told me what I had to do,
  This dear old Liljencrantz.

He told me that on Tuesday night,
  The first in nineteen two,
I was to come "all cocked and primed"
  To talk a while to you.

He fixed a hard condition, tho',
  Which almost made me stop,
For, he said, "just talk of anything—
  But mind you don't talk shop."

The shop is shut, the forge is cold;
  No hammer strokes are ringing,
The many tongues of industry
  Have ceased their chorus singing.

And other songs are ours tonight,
  And other voices mingle
In comrade chorus loud and strong
  To make the warm heart tingle.

'Tis time to talk of many things,
  More things than I can mention;
If some of these should be forgot,
  Don't blame my good intention.

And first I will begin at home;
  Our ballots now are tallied
And Finley is the President
  To whom we all have rallied

Three cheers for him, a tiger, too,
For we are glad he won it;
He'll serve his term so well, I know,
We'll be sorry when he's done it.

We always follow goodly men,
Our calling's finest fruit,
And ripe in wisdom, rich in lore
Is our own beloved Chanute.

Chanute, who in the ambient air
On lightest wing goes gliding,
While we, who plod in trodden paths,
Look up and praise his riding.

And now we'll say a word or two
About our world and nation,
And mention men of high degree
And most exalted station.

There was a Spanish navy once,
Which, like the great Armada,
Sailed out upon the ocean blue
To be a bold invader.

Now part of it is lying deep
In far Manila Bay,
And part of it on Cuba's coast
In ghastly wreckage lay.

For Dewey's ships sailed in and sunk
Montejo's brave flotilla;
That's what he did one early morn
By far away Manila.

Cervera shared no better fate
When Schley, the hero, fought him;
The lesson that he learned that day
Was one disaster taught him.

"There's glory enough for all," said Schley,
When the guns had ceased to thunder.
We've looped our loop, we've sunk their fleet,
And the Spaniards have gone under.

A glory he was glad to share
With all who fought beside him,
Was grudged to him who did the deed,
And justice was denied him.

His honor was too dear a prize
To yield to base detraction;
To yield to envy, hate and pique,
The fame he'd won in action.

A court convened to try the man
Whose flag was bathed in glory,
And judges, three, sat patiently
To hear the thrilling story

Of how a great Commander stood
'Mid battle's smoke and thunder
And wrought a victory so grand
That nations paused to wonder.

They wondered then and wonder now
  How deeds that were so splendid,
Could find a foe to cry them down
  In the land that he defended.

Here the note was put into the hopper with the following result;

### VIRGINIA.

Virginia! land of legends
  That thrill the heart with pride,
Whether they tell of plenteous peace
  Or war's red flowing tide.

Virginia! nature blessed thee
  With beauteous scenes and rare;
In all the lands, in all the climes
  The eye finds naught more fair,—

At least her children think so;
  For those she brought to birth
No spot is found on alien ground
  Dear as her own green earth.

They love her brooks that tumble
  All down the mountain side,
They love her rivers' onward flow
  To meet old Ocean's tide,

They love her rugged mountains,
  From whose peaks they may look down
Upon her peaceful valleys, spread
  With harvest ripe and brown.

God made the old land to be loved;
  His pious law we keep
While life is ours, and on that soil
  We'll seek our long, last sleep.

Virginia's sons in other days
  Have graven many a name
High on the walls where duty calls,
  And fadeless is their fame.

Who led the patriot armies
  Through those desperate years of strife?
Who turned defeat to victory
  And gave a nation life?

A Virginian bore the banner,
  And while he held it high
The men who fought beside him swore
  This nation shall not die.

Right well the oath that bound them
  Was kept till victory came
And Yorktown saw the British arms
  Laid down: you know that name!

When the land was stirred to action
  And each sword forsook its sheath,
Twas Henry's voice inspired brave souls
    For "liberty or death."

Twas Jefferson whose pen was dip't
  In eloquence and truth .
To draw the Declaration right
  In our nation's budding youth

'Twas Light Horse Harry Lee
  Who rode the hapless foeman down
And Marshall kept the ermine pure
  Of the first Chief Justice gown.

Go read upon that earlier page
  The names we're proud to bear,
And count the goodly number
  Of old Virginians there.

Then follow down the march of time
  With which our land kept pace,
And note the many in the van
  Of that old Virginian race.

I know that you who hear me
  Think not as I once thought,
When lines were drawn and strife was on,
  And the land was overwrought.

You never felt the thrilling
  Of the "good old rebel" song;
Your pulses never quicker beat
  When Dixie rolled along.

But you honor deeds of daring
  By whomsoever wrought;
Each hero's name is dear to fame,
  'Neath whichever flag he fought.

Stern Thomas clung to the starry flag,
  Which he scan'd like an ancient augur,
And the southern avalanche was turn'd
  By this "Rock of Chickamauga."

While under the silken folds that bear
  The arms of his native state,
Lee drew his sword and vow'd to share
  That grand old Mother's fate.

And Stonewall Jackson swept across
  Those harvest fields of strife,
Leaving a swath of victory
  Which ended with his life.

I pause, to fold the long proud list
  Of these whose glorious dust
Now mingles with the soil they loved,
  But whose souls dwell with the just.

Brave hearts, we know their pulsing
  Was ever strong and true,
Whether they throbbed beneath the grey
  Or beat beneath the blue.

They faced the gauge of battle
  And measured hero high,
These sons of old Virginia
  In the bloody days gone by.

What can I say, where find the words
  I need above all others
In telling fitly what we owe
  Our dear Virginia mothers.

Mothers whose charm of face and form
  Was but the outward showing
Of inward grace and tenderness
  And true hearts warm and glowing.

I cannot do it worthily,
  And words are overladen,
When they essay to tell the charms
  Of the dear Virginia maiden.

Suffice it; when I yearned to wed
  Love flew on steadfast pinion,
And won for me that priceless prize—
  A wife, who's all Virginian.

*The Chairman*—Gentlemen, after listening to Mr. Randolph's verse, I am satisfied that you will all join me in being willing to transfer our allegiance from Omar, the Persian Tent-Maker, to Randolph, the Canal Builder.

I regret that Mr. L. E. Cooley is unavoidably absent. He was down to respond to the toast of "The use of Coolie Labor in Engineering Construction."

We will next call upon General Sooy Smith to respond to the toast "On the Spur of the Moment."

### "THE SPUR OF THE MOMENT."

*General Smith*—Mr. President and Gentlemen of the Western Society of Engineers: It is unfair to place me in this position, and I make the charge publicly against the Secretary, our Secretary. He told me this afternoon that I was booked for a speech, and he asked me the subject. I told him I could not make a speech in that way, that I had no subject. "Well," he said, "you will have to speak on the spur of the moment, and that will account for my subject."

However, fortunate circumstances have favored me, and I have a spur to a speech this moment, as I gaze into the face of an honored visitor that we have from that great and glorious old country, Germany. We are glad to welcome him here; we are glad to hear him say that we have works in this country which command his admiration. We have come up to this standard from a very small beginning, and well for us is it that it is so. We learned in the infancy of the profession of Civil Engineering in the United States to make the most of very slender resources, and in this we learned the fundamental principle which underlies the success of the profession and the success of each member of the profession. He who can do most with the means at hand, to build great and good works on sound principles, is the best engineer. And it is unfortunate for a man, or a body of men, representing our profession, to come up under circumstances in which the means of accomplishment are away beyond the necessities of it. In a trip I made through Europe I discovered the effect of that set of circumstances. I saw everywhere works to command my highest admiration, but almost everywhere I could see great waste This they have somewhat corrected, but in the economical use of materials I think our friend will acknowledge that we now lead the world.

We have got our very great skill in engineering, our knowledge of the science of engineering, and more especially of the art of engineering, from the circumstances which have surrounded us, and it is the duty and the interest of every member of our profession to remember this and be guided by it

I am glad to see the representatives here of the different ages of civil engineers in our country. Some of us wear locks that are white as snow, and others are in the bloom and beauty of youth. To all of you I say hail! In the face of every one of you I see a friend, I see one to whom I am a friend, and especially to the young men of our profession. It is the duty of us who have reached the advanced age that we have, and such success as we have won, and such things as come to us with that success, to hold out a helping hand to the young men who are coming into our profession, full of hope, full of noble ambition, with such thorough training as they are now getting, in as good technical schools as the world can boast of, it is our duty to give to them every opportunity we can, every encouragement we can every motive to do good, honest, hard work; for out of that comes our success

And I think this is the proper gauge of the civil engineer, the work that he performs. Let that speak for us. We need no newspaper reporters to make us famous—if we ever hope to be famous—on good solid ground. Let our works speak for us. And those of us who are happy enough, fortunate enough, by accident or otherwise, to add anything to the art of engineering, or to the science of engineering, may feel, although we are the poorest paid profession in the world, yet we can feel that we are honorable, and at the end of our lives we can feel that we have not lived in vain. We have left the world wiser and better for our having been in it.

All honor to every young man who is entering our profession with the high resolve of doing first-rate, honest work. And honesty is the foundation of all true success in it. That is the praise that belongs to us beyond any profession in the land. We feel proud of it, that the civil engineer stands between those who do the work in all great undertakings and those who pay for them, to see that everything is honestly managed, and honestly done.

I bid the young men hail! To us who have grown old is the pleasure of retrospect, it is delightful to look back through long years of earnest toil, however little we may have accomplished. We have committed our mistakes, but they are pardonable. No human being is perfect.

To the young man coming into the profession today, I would say there is no information he should overlook. From the engineer-in-chief down to the man in the ranks, we have the most intelligent co-laborers on the face of the earth. Through their efforts, our own are made successful. Our machinery is the best in the world and is now being copied throughout the world—and it deserves to be. We do by the services of a single man, with such machines as we invent, the labor of an hundred. This wipes out the advantages the old nations had over us in cheap labor. Our labor is the cheapest in the world, because it is the best.

God Almighty gave us the greatest resources in the world. Nowhere on the earth are there such tremendous deposits of those valuable materials which are necessary in our works. These resources are being developed on a wonderful scale. At the same time we have today developed a skill in our workmen, in the individual, which makes the American nation great.

And here, let me say to you, young men, whatever suggestions come to you, no matter what the difficulties surrounding you may be, follow out the suggestions, study them honestly, take into consideration all the facts, draw logical conclusions from them, whether they are favorable to your predisposed opinions or not, and decide accordingly; and strive above all things to find out whether you are wrong or not. It is much better that you do so, and you are on the true road to success.

Now, we have been treated to some poetry. There is one bit which I remember, and which is perhaps appropriate to this occasion, as an inspiration to those of you who are indulging in the "Pleasures of Hope:"

"At summer eve, when Heaven's ethereal bow
Spans with bright arch the glittering hills below,
Why to yon mountain turns the musing eye,
Whose sunbright summit mingles with the sky?
Why do those cliffs of shadowy tint appear
More sweet than all the landscape smiling near?
'Tis distance lends enchantment to the view,
And robes the mountain in its azure hue.
Thus, with delight, we linger to survey
The promised joys of life's unmeasured way;
Thus, from afar, each dim discovered scene
More pleasing seems than all the past hath been,
And every form, that Fancy can repair
From dark oblivion, glows divinely there."

*The Chairman*—I will next call upon our brother, Mr. Karner, and will pay him the distinguished compliment of not assigning a subject.

*Mr. Karner*—Mr. President and Gentlemen

I fear I am in a sorry plight
To say much to entertain you here tonight.
The part by the Committee to me assigned,
If I rightly call my instructions to mind,
Is not to "talk shop" but give you something in rhyme.

Well, I frankly confess there was a time
In days of yore, when time was young,
And birds conversed as well as sung,
That I thought I was quite a poet
And wanted all the world to know it.

To earn some money to buy store clothes
I wrote machine poetry, not heavy prose;
On a Chanute glide I soared aloft
Until some people said my brain was soft.
Soft was what they said, but, bless you; sir,
It was the toughest proposition since Ben Hur
Circled the arena at a breakneck pace
And won his International chariot race.

But with such flights I will not tax
Your patience longer, but come down to facts;
'Tis said this world is all a fleeting show
For man's delusion given.
That may be true, but then you know
We are all quite fond of the fleeting show.
So let the wide world wag as it will,
We'll be gay and happy still.
If some of my quotations are a trifle stale,
Remember, please, they're not borrowed from Cornell or Yale.
One day, while standing on State and Madison street,
Jostled by the crowd that trampled on my feet
As the shoppers passed by, their bills to pay,
My thoughts ran along in about this way:
This life is one continuous tussle;
For food and clothing we all have to hustle;
And the man who is not of his reason bereft
Must look out sharp or he is sure to get left.
Some kick, some scold, and others declare
The good things of life are not divided fair;
It does them no good to be so perverse,
They all ought to know things might be much worse.
The bank may break, your dump may get wet,
It does you no good to fume and to fret.
Watch for clear skies. The sun will shine by and by,
And in a few hours your dump will get dry.
You may suffer with a bad stomach ache
From eating and gorging too much pie and cake;
But I think you'll agree I'm not talking through my hat
When I say appendicitis is much worse than that.
Though five feet ten, and continuous as far as I go,
I do not wish to monopolize this entire show;
But to my fellow members, I will now propose—
After I bring this "melange" to a close—
We drink the health of officers both present and past,
Assuring the new we'll stand by them to the last,
And promise this year to do our level best
To make our Western Society a power, both East and West.

With thanks for your attention and good will, I think
I will stop this jingle and give you time to drink.

*The Chairman*—I think that the exercises would not be appropriately closed unless we called upon Mr. Horace E. Horton. I tried to induce him to act as toastmaster of the evening, but he would not.

*Mr. Horton*—Gentlemen, I notice it is ten minutes past 11 o'clock, and I have to take a train at 11:30; hence, and for the further reason that I never was known to make any remarks after 11:10, you will excuse me at this point.

*The Chairman*—Gentlemen, if there are no objections we will consider the meeting closed, and follow Mr. Horton to the rear.

The meeting then adjourned.

## ANNUAL REPORTS.

### TREASURER'S REPORT.

JANUARY 7, 1901.

*Board of Direction Western Society of Engineers, Chicago.*

GENTLEMEN I respectfully submit herewith a statement of the Treasurer's account for the year 1901, as follows:

| | | | | |
|---|---|---|---|---|
| January 1, 1901, Cash on hand | | | $2,496.15 | |
| RECEIPTS. | | | | |
| Entrance fees | | $ 723.00 | | |
| Dues | | 4,636 56 | | |
| Journal, | | | | |
| Advertising | $2,678.77 | | | |
| Subscriptions | 346.50 | | | |
| Sales | 151.36 | | | |
| Copyright rebate | 2.50 | 3,179.13 | | |
| Rent | | 127.70 | | |
| New room | | 2.00 | | |
| General printing | | 34.45 | | |
| Library | | 40.11 | | |
| Stationery and postage | | 24.76 | | |
| Interest on deposit in bank | | 66.64 | | |
| Sundries | | 61.05 | | |
| Medals | | 100.00 | 8,995.40 | 11,491.55 |
| DISBURSEMENTS. | | | | |
| Journal, 1900 | | 448.11 | | |
| " 1901 | $2,301.07 | | | |
| " 1901, services | 817.70 | 3,118.77 | | |
| Library | 419.92 | | | |
| " services | 449.80 | 869.72 | | |
| Services | | 1,939.82 | | |
| General printing | | 595.28 | | |
| Stationery and postage | | 565.97 | | |
| House expense | | 1,393.22 | | |
| Entrance fees (returned) | | 5.00 | | |
| Sundries | | 101.10 | | |
| Medals | | 100.00 | 9,136.99 | |
| December 31, 1901, Cash on hand | | | 2,354.56 | 11,491.55 |

Memo—Of the cash on hand ($2,354.56) in bank, the sum of $2,000.00 is in certificates of deposit as follows:

| | | |
|---|---|---|
| One certificate falling due March 12, 1902 | $1,000.00 | |
| " " " " May 6, 1902 | 500.00 | |
| " " " " Sept. 27, 1902 | 500.00 | 2,000.00 |

Respectfully submitted, RALPH MODJESKI, Treasurer.

## REPORT OF FINANCE COMMITTEE.

CHICAGO, January 7, 1902.

*Board of Direction Western Society of Engineers, Chicago.*

GENTLEMEN—Your Committee respectfully submits the following conservative estimate on the financial condition of the Western Society of Engineers at the closing of the fiscal year 1901:

RESOURCES.

| | | | | |
|---|---|---|---|---|
| Cash on hand December 31, 1901 | | | $2,354.56 | |
| Dues unpaid | | $146.70 | | |
| Entrance fees unpaid | | 20.00 | | |
| Rent unpaid | | 20.00 | | |
| Journal, | | | | |
| Advertising, 1900 | $158.00 | | | |
| " 1901 | 113 00 | | | |
| Subscriptions, 1900 | 22.00 | | | |
| " 1901 | 15.00 | 308.00 | | |
| Journals (stock on hand, estimated) | | 600.00 | 1,094.70 | 3,449.26 |

LIABILITIES.

| | | | |
|---|---|---|---|
| Accounts payable | | 280.00 | |
| Advance collections, | | | |
| Advertising, 1902 | 27.00 | | |
| Subscriptions, 1902 | 5.75 | | |
| Dues, 1902 | 27.30 | 60.05 | |
| Profit and loss | | 3,109.21 | 3,449.26 |

Finance Committee, { W. H. FINLEY,
R. MODJESKI,
C. W. MELCHER.

## REPORT OF THE AUDITING COMMITTEE, 1901.

CHICAGO, January 7, 1902.

*Board of Direction Western Society of Engineers, Chicago, and Members:*

GENTLEMEN—Your auditing Committee respectfully reports that it has carefully compared the accompanying reports of the Secretary and Treasurer with the books of the Society, and finds that they agree therewith, and that all receipts and expenditures have been duly accounted for.

Respectfully submitted.

ANDREW S. ALLEN,
T. L. CONDRON,
GEO. A. DAMON.

## RECEIPTS, 1901.

| Months, 1901. | Entrance Fees. | Dues. | Advertising. | Subscriptions. | Sales Journal | Rent. | General Printing. | Library. | Sta. and Postage. | Interest. | Sundries. | Medals. | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January.............. | $ 69.00 | $1759.18 | $ 351.50 | $132.50 | $ 8.15 | $ 23.85 | $ .45 | .......... | .......... | .......... | $ 6.05 | $100.00 | $2450.98 |
| February............. | 33.00 | 350.00 | 174.00 | 24.50 | 5.70 | 26.70 | .......... | $ .30 | .......... | .......... | 55.00 | .......... | 669.20 |
| March............... | 123.00 | 320.00 | 71.00 | 20.00 | 32.90 | 12.50 | .......... | .......... | .......... | .......... | 2.00 | .......... | 581.40 |
| April. .............. | 65.00 | 502.63 | 270.00 | 20.00 | 14.90 | 19.35 | .......... | 4.25 | .......... | .......... | 2.50 | .......... | 898.63 |
| May.................. | 99.00 | 400.10 | 85.00 | 30.00 | 12.80 | 18.35 | 7.75 | .......... | $12.50 | .......... | .......... | .......... | 665.50 |
| June................. | 38.00 | 281.69 | 74.00 | 12.00 | 13.05 | 1.25 | .......... | .......... | 2.50 | $13.73 | .......... | .......... | 436.22 |
| July.................. | 73.00 | 316.60 | 10.00 | 23.75 | 8.40 | .......... | .......... | 1.00 | 2.50 | 44.70 | .......... | .......... | 179.95 |
| August............... | 40.00 | 172.50 | 335.37 | 12.00 | 23.80 | .......... | .......... | 28.65 | .46 | .71 | .......... | .......... | 613.19 |
| September........... | 63.00 | 114.99 | 139.50 | 20.00 | 3.57 | .......... | .......... | .......... | 5.00 | .......... | .......... | .......... | 346.06 |
| October.............. | 20.00 | 233.33 | 486.00 | 18.00 | 11.20 | 18.70 | .......... | .......... | 1.80 | .......... | .......... | .......... | 789.03 |
| November............ | 48.00 | 86.69 | 391.40 | 8.00 | 2.40 | .......... | .......... | .......... | .......... | .......... | .......... | .......... | 536.19 |
| December............ | 52.00 | 98.85 | 291.00 | 25.75 | 14.19 | 7.00 | 26.25 | 5.91 | .......... | 7.50 | .......... | .......... | 528.15 |
|  | $723.00 | $4636.56 | $2678.77 | $346.50 | $151.36 | $127.70 | $34.45 | $40.11 | $24.76 | $66.64 | $65.55 | $100.00 | $8995.40 |

Cash in hands of Treasurer January 1, 1900........................ 2496.15

$11491.55

## EXPENDITURES, 1901.

| Months, 1901. | Journal 1900. | Journal 1901. | Library. | House Expense. | Services. | General Printing. | Sta. and Postage. | Sundries. | Medals. |  |  |  | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January.............. | $448.11 | .......... | $112.50 | $113.60 | $226.87 | $ 53.70 | $49.20 | $15.90 | .......... | .......... | .......... | .......... | $1019.88 |
| February............. | .......... | $ 93.87 | 2.00 | 95.54 | 526.45 | 103.50 | 29.22 | 85.20 | .......... | .......... | .......... | .......... | 935.78 |
| March............... | .......... | 93.55 | .86 | 115.26 | 21.50 | 67.31 | 48.48 | .......... | .......... | .......... | .......... | .......... | 346.96 |
| April................ | .......... | 573.58 | .......... | 108.76 | 265.00 | 11.65 | 76.60 | .......... | .......... | .......... | .......... | .......... | 1035.59 |
| May.................. | .......... | 243.11 | 59.55 | 120.11 | 100.00 | 47.95 | 81.91 | .......... | .......... | .......... | .......... | .......... | 652.63 |
| June................. | .......... | 510.87 | 96.35 | 104.84 | 100.00 | 90.82 | 97.82 | .......... | .......... | .......... | .......... | .......... | 1000.70 |
| July.................. | .......... | 97.84 | 81.25 | 88.43 | 100.00 | 12.00 | 19.63 | 5.00 | .......... | .......... | .......... | .......... | 404.15 |
| August............... | .......... | 383.15 | 167.51 | 93.44 | 100.00 | 101.90 | 44.82 | .......... | .......... | .......... | .......... | .......... | 890.85 |
| September........... | .......... | 126.71 | 75.69 | 89.56 | 100.00 | 1.75 | 17.89 | .......... | .......... | .......... | .......... | .......... | 441.60 |
| October.............. | .......... | 371.64 | 86.15 | 137.48 | 100.00 | 13.00 | 26.05 | .......... | .......... | .......... | .......... | .......... | 734.62 |
| November............ | .......... | 419.81 | 53.23 | 96.18 | 100.00 | 15.85 | 11.50 | .......... | .......... | .......... | .......... | .......... | 696.60 |
| December............ | .......... | 113.43 | 61.40 | 129.61 | 100.00 | 38.05 | 35.60 | .......... | .......... | .......... | .......... | .......... | 478.69 |
|  | $448.11 | $3027.59 | $796.82 | $1292.81 | $1839.82 | $557.48 | $538.72 | $106.10 |  | .......... | .......... | .......... | $8607.45 |
| Dec. bills due in Jan. Paid Dec. 31, 1901.. |  | 91.18 | 72.90 | 100.41 | 100.00 | 37.80 | 27.25 |  | 100.00 | .......... | .......... | .......... | 529.51 |
|  | $448.11 | $3118.77 | $869.72 | $1393.22 | $1939.82 | $595.28 | $565.97 | $106.10 | $100.00 | .......... | .......... | .......... | $9136.99 |

Cash in hands of Treasurer December 31, 1901.................. $2354.56

$11491.55

## SECRETARY'S REPORT.

JANUARY 1st, 1902.

*Board of Direction Western Society of Engineers, Chicago:*

GENTLEMEN—Herewith I submit a tabulation of the increase and changes in the membership list of the Western Society of Engineers up to December 31, 1901. This shows a net gain of fifty-six (56) members, or a total membership of 558. This does not include thirteen (13) members who were elected Dec. 31, 1901, but have not yet qualified.

| | January, 1901. | | | January, 1902. | | | Additions, 1901. | | Losses, 1901. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Resident. | Non Resident. | Total. | Resident. | Non Resident. | Total. | Transfer. | Elected. | Deaths. | Resigned. | Transfer. |
| Hon. Members.... | 1 | ... | 1 | 1 | .. | 1 | ... | ... | ... | . . | ... |
| Active Members... | 266 | 161 | 427 | 286 | 185 | 471 | 3 | 67 | 8 | 18 | ... |
| Associate Members | 27 | 1 | 28 | 25 | 3 | 28 | ... | 2 | ... | 2 | ... |
| Junior Members . | 21 | 25 | 46 | 27 | 31 | 58 | ... | 16 | ... | 1 | 3 |
| Totals.......... | 315 | 187 | 502 | 339 | 219 | 558 | 3 | 85 | 8 | 21 | 3 |

There have been eight deaths of Active Members and twenty-one resignations, the past year. Other resignations have also been tendered to take effect with the close of this year, but are not shown in this table.

List of deceased members:

March 17th, Professor N. O. Whitney, Madison, Wis.
May 20th, Mr. John McIntyre, Chicago.
July 23rd, Mr. Jas. F. Lewis, Canada.
June 21st, Mr. F. H. Davies, Chicago.
Sept. 22nd, Mr. Jas. M. Healey, Minneapolis, Minn.
Sept. 24th, Mr. Irving Hitz, Chicago.
Sept. 28th, Mr. Wm. Jackson Yoder, Tiffin, Ohio.
Dec. 17th, Mr. Benj. Reece, Wilmington, Delaware.

There have been held twenty-four meetings during the year 1901. This includes the Thirty-first Annual Meeting, at the Grand Pacific Hotel and one meeting held in the Art Institute. It also includes two "Smokers" held in our own rooms.

There have been presented thirty papers at these meetings, a list of which is attached.

*Tuesday Evening, January 8, 1901.*

31st Annual Meeting at Grand Pacific Hotel. Addresses on "The Improvement of the Chicago River."

*Wednesday Evening, January 23, 1901.*

Northern Pacific Standard Bridge Plans, by Ralph Modjeski.
Rail Top Culverts, by Albert Reichmann.
Bridgeport Wheel Pumps, by Ossian Guthrie.

*Wednesday Evening, February 6, 1901.*

Factors which Cause the Decay of Wood, by Prof. Hermann von Schrenk.
The Subscructure of the Glasgow Bridge, by H. P. Boardman.

*Wednesday Evening, February 13, 1901.*

The Chicago River, by T. T. Johnston, at The Art Institute, with discussion.

*Wednesday Evening, February 20, 1901.*
Concrete Masonry Canal Locks, by Maj. J. B. Long.
Some Old Examples of Bascule Bridges, by K. Hellenthal.

*Wednesday Evening, February 27, 1901.*
"Smoker."

*Wednesday Evening, March 6, 1901.*
Discussion of Mr. H. P. Boardman's Paper, "The Substructure of the Glasgow Bridge."
Discussion by Mr. Jas. A. Seddon of Maj. C. McD. Townsend's Paper, "Reservoirs and the Control of the Lower Mississippi."

*Wednesday Evening, March 20, 1901.*
The Art and Craft of the Machine, by F. L. Wright.

*Wednesday Evening, April 3, 1901.*
The Piers of the Midland Railway Bridge Over the Schubenacadie River, Bay of Fundy, Nova Scotia, by Geo. E. Thomas.

*Wednesday Evening, April 17, 1901.*
Some Engineering Problems in Cement Manufacture, by Prof. S. B. Newberry.

*Wednesday Evening, May 1, 1901.*
A Simple Method of Determining the Conditions of Combustion, with Suggestions on Working Furnaces, by A. Bement.
Boiler Tests with Illinois Coals, by Prof. L. P. Breckenridge.

*Wednesday Evening, May 8, 1901.*
Electrical Oscillations of High Frequency, by A. V. Abbott.

*Wednesday Evening, May 15, 1901.*
The Water Works System of Chicago, by J. H. Spengler.

*Wednesday Evening, May 22, 1901.*
A Central Railway Terminal for Chicago, by R. C. Sattley.

*Wednesday Evening, June 5, 1901.*
Discussion of Mr. Geo. S. Morison's Paper, "The Effects of Splicing and Riveting."
Discussion of Mr. J. H. Spengler's Paper on "The Water Works System of Chicago," by John Ericson and others.

*Wednesday Evening, June 26, 1901.*
The Forester an Engineer, by Prof. B. E. Fernow, Ithaca, N. Y.

*Wednesday Evening, September 4, 1901.*
Modern Practice in Bridge Shop Work, by W. H. Pratt.

*Wednesday Evening, September 18, 1901.*
Aerial Navigation; Some Late Gliding Experiments, by Wilbur Wright.

*Wednesday Evening, October 2, 1901.*
The Washing of Bituminous Coals by the Luhrig Process, by J. V. Schaefer.

*Wednesday Evening, October 16, 1901.*
"Smoker."

*Wednesday Evening, November 6, 1901.*
The Protection of Water Pipe from Electrolysis, by E. B. Ellicott.

*Wednesday Evening, November 20, 1901.*
The Co-efficient of Expansion of Concrete, by Prof. W. D. Pence.
The Protection of Metal Work of Ballasted Bridge Floors, by W. H. Finley.

*Wednesday Evening, December 4, 1901.*
A Proposed Dam and Water Power on the Mississippi River at Keokuk, Iowa, by Lyman E. Cooley.

*Wednesday Evening, December 18, 1901.*

Fire-proof Grain Elevator Construction, by James Macdonald.

Discussion of Mr. D. W. Mead's Paper on "A Gas Engine Driven, Direct Pressure, Pumping Plant, with Some Experiments on Pump Valve Area."

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## REPORT OF THE LIBRARY COMMITTEE.

January 7, 1902.

*To the Board of Direction, Western Society of Engineers*:

*Gentlemen*—The attached report of the Librarian of the Western Society of Engineers is complete and meets entirely with the views of your Committee. We concur in his recommendations.

Respectfully submitted,
B. J. Arnold,
Ralph Modjeski,
H. P. Boardman,
Committee on Library.

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## LIBRARIAN'S REPORT.

January 7, 1902.

*To the Library Committee, W. S. E.*

*Gentlemen*: I respectfully submit the following report on the Library of the Western Society of Engineers for 1901:

| | | |
|---|---|---|
| Total number of books accessioned to December 31, 1901...... | | 3,975 |
| Total number of books accessioned to December 31, 1900........ | | 3,623 |
| Increase in number of books in library...................... | | 352 |
| This includes bound books acquired by purchase.............. | 6 | |
| Books bound by society .................................. | 7 | |
| Periodicals bound by society ............................ | 70 | |
| Bound volumes received by gift and exchange................. | 269 | 352 |
| | 352 | |

Our exchanges have been increased in numbers, and are now about as follows:

Fifty-five Foreign Exchanges, 31 Chicago Exchanges; (8 Weekly, 17 Monthly, 1 Bi-Monthly, 1 Quarterly and 4 Annuals), and 100 from other cities in America, as follows: 21 Weekly, 4 Semi-Monthly, 49 Monthly, 4 Bi-Monthly, 10 Quarterly, 1 Semi-Annual and 20 Annual.

In addition to the above actual increase to the library the society has received gifts of odd numbers of books, pamphlets, periodicals, catalogues of schools, etc., etc., all of which have been duly noted in the "Journal" under the heading of "Library Notes."

The charge against the library on the Secretary's books is $735.42, and credit is given the library of $34.20, leaving a net charge against the library of $701.22.

This includes $389.20 for that part of the salary for eight months' services of the Assistant to the Secretary as time charged to the library.

There was also charged against the library the cost of a new typewriting machine and a few minor improvements to the furniture.

Permit me to call to your attention the cramped condition of the library—the lack of shelf room for our constantly increasing list of books. Until other arrangements be made, giving additional room, I would recommend the purchase of some glass front sectional bookcases of the Globe-Werneke type—say four cases high and two cases wide—which could be placed in one corner of the reading room, for the holding of the Cyclopedia, Century Dictionary and a few other such books which are more frequently consulted.

The cost of such a set of cases would be about $30.00 or less.

On my own responsibility I have installed a clock on the wall over the Secretary's desk, which is of advantage on meeting nights and at other times. The rental of this is $4.00 a year and is charged against the library.

In the main meeting room the lighting from the ceiling has not been satisfactory, and lately there has been put in glass globes over the ceiling electric lights of the Holophane type. These are put in provisionally and on trial. The cost of these twelve globes and holders, if kept, will be $9.20. The question of improvement remains to be decided upon.

This society has been preparing a Card Catalogue of current technical literature by taking the monthly lists published by the Engineering Magazine, cutting them up and mounting on cards. This work is incomplete, as these cards need to be classified and numbered according to the Dewey System. The work that has been done is of no service to our readers until this classification is accomplished. The cost of this classifying and numbering by a cataloguer is, I suppose, to be about $1.00 per 100 cards,—(1 cent apiece). There are some 4,000 or 5,000 cards, if not more, now awaiting this work, and I would respectfully urge you to authorize this work, and thus give to our library a most valuable card index to current technical literature.

Very respectfully submitted,

J. H. Warder,

Librarian.

## REPORT OF COMMITTEE ON EXHIBIT AT THE PARIS EXPOSITION.

January 4, 1902.

*To the Board of Direction, Western Society of Engineers.*

*Gentlemen*: Your Committee on the Paris Exposition desires to submit the following report:

The Committee has co-operated as much as it was in its power with Mr. Willard A. Smith, Director of Transportation and Engineering, in securing as many exhibits as possible. The result of the combined effort was highly gratifying. Your Committee will not enumerate here all the objects which have been exhibited under the auspices of the Western Society, but will be satisfied with mentioning only a few of them. The Sanitary District exhibit, which was one of the finest engineering exhibits at the Exposition, occupied part of the main floor of the engineering section. On the same floor was placed the extremely complete architectural exhibit secured by one of the members of your Committee. Among other objects exhibited was a beautiful model of a Howe Truss Bridge, contributed by the Chicago, Milwaukee & St. Paul Railroad, also a model of a ballasted trestle, contributed by the Illinois Central Railroad. There were not less than two thousand photographs of various engineering subjects exhibited. These photographs were placed in the gallery above the ground floor.

The Western Society exhibited a number of volumes of its Transactions, for which it has been awarded a Silver Medal, the only Gold Medal having been awarded to the American Society of Civil Engineers.

The Committee desires to report further that the model of the Howe Truss Bridge was presented by the Chicago, Milwaukee & St. Paul Railroad to the French National School of Bridges and Roads (Ecole des Ponts et Chaussees) and is now exhibited in their model room. Some of the other models and all the photographs have been presented to various engineering societies and schools of France.

Your Committee desires to thank the members of the Society for their hearty co-operation in attaining their object.

Respectfully submitted,

Ralph Modjeski,
Isham Randolph,
Congdon T. Purdy,
B. J. Arnold.

### *SPECIAL MEETING—January 15, 1902.*

A Special Meeting of the Western Society of Engineers (No. 462) was held the evening of January 15, 1902, with President Finley in the Chair and about fifty-five (55) members and guests (including eight ladies) present.

As this was a special meeting, there was no business to be transacted.

The President introduced Mr. P. A, Maignen, of Philadelphia, Assoc. Am. Soc. C. E., who addressed the Society on "Water Purification and Filtration." This was illustrated by about thirty-five lantern slides, some apparatus and filtering material, including a few small domestic filters, with which some experiments in filtration were performed.

Some discussion followed from Messrs. Alvord, C. D. Hill, Condron and Vorce.

In conclusion, on motion of Mr. C. D. Hill, a vote of thanks was returned to Mr. Maignen for his interesting and instructive address.

The meeting adjourned about 10:45 P. M.

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### *REGULAR MEETING—February 5, 1902.*

A regular meeting (No. 463) of The Western Society of Engineers was held February 5, 1902.

The meeting was called to order at 8:30 P. M. with President Finley in the Chair and about fifty members and guests present.

The reading of the minutes of the annual meeting held at the Auditorium January 7 and the minutes of the special meeting of January 15 was dispensed with.

The following list of new applications was presented by the Secretary:

Chester D. Bradford, 142 54th street, Chicago, Active.
L. D. Vorce, 5225 Madison avenue, Chicago, Active.
Sutton Van Pelt, Greenwood. Ala., Junior.
Wm. Pierce Hoppin, 6201 Woodlawn avenue, Chicago, Junior.
Maro Johnson, 5412 Washington avenue, Chicago, Junior.
Robert Isham Randolph, Riverside, Ill., Junior.
F. A. Flather, Lowell, Mass., Active.
M. W. Tenny, Holly, Mich., transfer from Junior to Active.
Wm. Meier, 300 N. Paulina street, Chicago, Junior.
Wm. A. Theodorson, 19 Milton avenue, Chicago, Junior.
Edgar B. Thompson, Oak Park, Ill., Active.
J. C. Quade, Kewanee, Ill., transfer from Junior to Active.

The Secretary announced the death of two of our members: Mr. Morritz Lassig, 1784 Deming court, this city, January 7, 1902, and Mr. Edward Langford Adams, Austin, Ill., January 31, 1902.

The Chairman said the usual action would be taken and that memorials would be prepared.

The Secretary announced, on behalf of the Entertainment Committee, that there would be an entertainment in the Society rooms Friday evening, February 15, at which time Mr. W. J. Karner would give an illustrated lecture on "A Trip from Paris to Brussels."

Following this, the paper for the evening, on "Sewage Purification Plants," was presented by Mr. J. W. Alvord, illustrated with many lantern slides. Discussion followed from Messrs. Finley, Bainbridge, Torrance, Potter, Prof. Talbot and C. D. Hill.

The meeting adjourned at 10:30.

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### *SPECIAL MEETING—February 15, 1902.*

A Special Meeting (No. 464) of The Western Society of Engineers was held Saturday, February 15, 1902.

This was "Ladies' Night," and as the Society Rooms were not large enough to accommodate the members and their guests, the entertainment was held in Assembly Hall of Fine Arts building (Studebaker's), on Michigan avenue.

Mr. W. J. Karner, M. W. S. E., gave an interesting illustrated lecture on travel, "From Paris to Brussels."

After the lecture refreshments were served, and the remainder of the evening was spent in an informal and impromptu dance.

There were about 250 members and guests present.

J. H. WARDER, Secretary.

## LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL we have received the following gifts from the doners named:

Victor C. Alderson, pamphlet, "German Technical Schools."

Borden & Selleck Co., Chicago, pamphlet, "Conveying and Elevating Machinery." Catalogue No. 5.

Metropolitan Water Board, Boston, Mass., 5 vols. cloth and one pamphlet, 1st to 6th inclusive annual reports 1896-1901.

P. Blakiston's Son & Co., Philadelphia, Pa., one 8 vo. cloth bound volume, "A Laboratory Guide to Qualitative Analysis." Bailey & Cady.

State Board of Health, Mass., one 8 vo. cloth bound volume, 32nd Annual Report, of the State Board of Health.

E. E. R. Tratman, one cloth bound volume, "The Westinghouse High Speed Brake."
Three pamphlets, "Traction by Steam Storage" (fireless locomotives), French practice.

Edward Flad, Water Commissioner, St. Louis, Mo., one pamphlet, Annual Report Water Commissioner of St. Louis, April, 1901.

H. N. Elmer, Trenton Iron Co., Chicago, one pamphlet, 1895, "Steam and Electric Logging Cableways."

Prof. B. E. Fernow of New York State College of Forestry, one pamphlet, "Third Annual Report for 1900."

Arthur S. Ives of R. D. Wood & Co., Philadelphia, one book, cloth, Trade Catalogue, "Water and Gas Works Appliances and Pumping Machinery."

American Society of Mechanical Engineers, one volume, paper, Proceedings of Fall Meeting, 1900, and Spring meeting, 1901, at Milwaukee.

American Water Works Association, New York, one volume, paper, Proceedings of 21st Annual Meeting, New York, 1901.

New England Cotton Manufacturers' Ass'n., Boston, Mass., one volume, bds., "Transactions of Semi-Annual Meeting, Niagara Falls, September 25th, 1901."

P. Blakiston's Son & Co., Philadelphia, one volume, cloth, "Water and Water Supplies," by J. C. Thresh.

Boston Transit Commission, one cloth bound volume, Seventh Annual Report, August 15, 1901.

Institution of Electrical Engineers, London, Journal, Vol. No. 31, Proceedings International Congress at Glasgow, 1901.

The New York World Publishing Co., the "World Almanac for 1902."

Thonindustrie-Zietung, Berlin, "Thonindustrie Kalendar for 1902."

National Meter Company, New York, Trade Catalogue 1901, "Nash Gas and Gasoline Engines."

B. F. Sturtevant Co., Boston, Catalogue No. 119, Sturtevant Exhaust Head.

U. S. Department of Agriculture, pamphlet, "Tree Planting on Rural School Grounds," by W. L. Hall.

Air Brake Association, Proceedings Eighth Annual Convention, 1901.

Institution of Engineers, Chile, Proceedings 1901, September and November, Nos. 5 and 6.

U. S. Bureau of Education, pamphlet, American Learned and Educational Societies, 1896.

" " " pamphlet, Public, Society and School Libraries, 1901.

W. S. Love, pamphlet, The Russian Empire and the Trans-Siberian Railway.
Pamphlet, Commercial Japan in 1899.
Pamphlet, Commercial Africa in 1899.

The above were issued by the U. S. Treasury Department, Bureau of Statistics.

Nine odd numbers, Engineering Magazine.
Two numbers, Street Railway Review.
One number, Street Railway Journal.

Wm. O. Seymour, Railroad Commissioner, State of Connecticut, one volume, cloth bound, Commissioner's Report for 1901.

Minister of Public Works, Argentine Republic, Buenos Aires, "Boletin of Obras Publicas de la Republica Argentina."

S. F. Patterson, Concord, N. H., Sec'y Association Railway Superintendents of Bridges and Buildings, pamphlet, Proceedings 11th Annual Convention, October, 1901.

Indiana Engineering Society, Proceedings 21st Annual Convention, 1901, Paper.

Western Wheeled Scraper Co., Aurora, Ill., Trade Catalogue Road Machinery, 1901.

I. C. Woodward, 1200 Fisher Building, Chicago, one book, 8 vo. cl., Catalogue of the Edge Moor Iron Co., Edge Moor, Del., Boilers, etc.

Automatic Water Purifying Co., New York City, pamphlet, Trade Catalogue Water Purifying and Softening Installations.

D. W. H. Moreland, Commissioner, Department of Public Works, Detroit, 25th, 26th and 27th Annual Reports, 1899, 1900, 1901.

Geo. P. Nichols Chicago, two volumes, paper, Transactions American Institute of Mining Engineers, Vols. XXVI and XXVII (1896 and 1897).

J. A. L. Waddell, Kansas City, Mo., one book, morocco, "De Pontibus," A Pocket book for Bridge Engineers.

Brooklyn Engineers' Club, one book, cloth bound, Vol. V, Proceedings for 1901.

G. B. Nicholson, Chief Engineer, C. N. O. & T. P. Ry. Co., Cincinnati, four volumes, one cloth and three paper, Reports Cincinnati Southern Railway, 1873, 1875, 1877, 1880.

D. Van Nostrand Company, New York, one cloth bound volume, "Power Transmitted by Electricity and applied by the Electric Motor, including Electric Railway Construction," by Philip Atkinson, A. M., Ph. D.

Geo. S. Morison, New York, one pamphlet, Address to Commercial Club, Chicago January 25, 1902, "The Isthmian Canal."

Hon. James R. Mann, Chicago, two pamphlets and a case of Maps, Document No. 149, 56th Congress, second session, Report of the Board of Engineers on Deep Waterways, 1900.

W. M Camp (Railway Review), 24 numbers, Transactions American Institute of Electrical Engineers.

Chicago Pneumatic Tool Co., Trade Catalogue No. 15 of Tools and Appliances

Angus Sinclair (Locomotive Engineering), 1 vol, flex leather. Block and Interlocking Signals. Elliott.

# BOOK NOTES.

**De Pontibus. A Pocket-Book for Bridge Engineers.** By J. A. L. Waddell. Flexible cloth binding. Size, 5x7 inches. First edition, second thousand. 403 pages. John Wiley & Sons, New York, 1901. Price, $3.00.

On first examining this book, one is tempted to criticise some of the minor points, such as the name given it and the author's tendency to overwork the pronoun, first person, singular. But knowing that the author's name stands for many years of engineering experience as a specialist, one may reasonably expect to find much valuable matter in its pages and not be disappointed.

One chapter of 18 pages is devoted to "The First Principles of Designing," and the author says that this chapter is by far the most important one in the book.

The chapter on "Æsthetics in Design" contains some ideas which might be studied with profit by bridge men in general and Chicago men in particular. The decorative effect of the bridges in and around Chicago seems to have been developed only in a negative direction. The author dwells at some length upon the methods to be used in beautifying American bridges, and many of the hints are of undoubted value, but the question naturally suggests itself: "Can it be possible that the designer of the Halsted street lift bridge could ever have read the author's chapter on Æsthetics in Design?"

Other chapters in the book are devoted to the cantilever bridges, arches, trestles and viaducts, elevated railroads, movable bridges, including rotating draws, counterweighted and rolling bascule bridges, lift bridges and floating bridges; highway and combined highway and railroad bridges; detailing; specifications for railroad bridge (72 pages); specifications for highway bridges (30 pages); specifications for steel; timber trestles; inspection of materials and workmanship. The designing of piers, triangulation and office practice are also the subjects of chapters.

In the back of the book are 18 tables and 10 plates of diagrams, giving values of various functions used in bridge designing.

A commendable and valuable feature of this book is the very complete index. G.

**A Laboratory Guide to the Study of Qualitative Analysis.** By E. H. S. Bailey, Ph. D., Professor of Chemistry, and Hamilton P. Cady, A. B., Assistant Professor of Chemistry in the University of Kansas. Fourth Edition. 12mo., 235 pages. Published by P. Blakiston's Son & Co., 1901. Price, $1.25.

The authors of this work plainly state their purpose in writing the book to be the broadening of the methods of instruction in qualitative analysis in such a manner as to teach not only the facts and methods employed in analysis, but also to render them more interesting and intelligible by a proper application of the theory of electrolytic dissociation and mass action. Accordingly, the first forty pages are devoted to the well-known laws of physical chemistry, especially to ionization and to mass action. The latter is illustrated by a number of mathematical equations and formulæ. Such terms as solution, concentration, precipitation, etc., are explained by reference to the laws above mentioned. Throughout the book the word "cation" is used in place of the word metal and "anion" instead of acid radical.

The "cations" are divided into seven groups: group I. comprises the alkalies, and group VII. includes lead, silver and mercury. The methods for separation of the groups are partly directive, partly descriptive, and partly explanatory—which is unfortunate from a pedagogical view-point.

The "anions" are divided into five groups, and methods for separating them are given. The tests selected are those commonly found in works on qualitative analysis, and are well presented; some entirely new tests are also entered.

A table for the preliminary examination of unknown substances and brief directions for putting them into solution are given, and a fairly complete table of solubility concludes the work. The pages with even numbers are left blank for the entry of notes. L. T.

**The World Almanac and Encyclopedia.** 1902. The Press Publishing Co., New York. Pamphlet, 5¼x7½ inches; 540 pages. Price, 25 cents.

A collaboration of everything in the line of such information as interests every man, woman or child in the world.

The New York World has succeeded in collecting and publishing in a concise and getatable manner, information touching almost every conceivable subject.

No industry is too insignificant to escape mention, and its statistics given, not only of its production in the United States but that of foreign countries in comparison. Events of every trifling importance, whether political, religious, sporting or criminal, are fully chronicled. Records of all natures, showing the past and present conditions of social, political, religious or sporting organizations, their growth and bearing in national affairs.

Tabulated records of elections since the Declaration of Independence; of sporting events for the last half century; statistics of all kinds, of every nature. Laws governing social, political, financial and sporting, and other affairs from a legitimate cab fare to the etiquette of a cabinet dinner. Lists of authors and their works, noted actors and actresses, noted men classed by their specialities, noted horses and their records.

A most complete collection of valuable and general information, such as every one has occasion to make use of almost every day in their lives, is here condensed, and it is hard to imagine a more useful accession to the home library, even though that library consists of but a few scattered publications over one's sitting-room table. Always interesting, even for a moment's occupation of time, it is the one book of all books which should lie about conveniently to hand for the spare moment's perusal.

It is authority for the settlement of the general run of disputes over past events, weather predictions and forthcoming events. L. A. N.

**The 13th, 14th, 15th and 16th Annual Reports of the Hydraulic Engineer on the Water Supply of Queensland, Australia, for 1897-1900 inclusive.**

"The waters under and over the earth," would be a fitting title for the last four annual reports of J. B. Henderson, M. I. C. E., M. Am. S. C., Hydrulic Engineer to the Water Supply Department of Queensland, Australia.

Not only is a careful study presented of the water-bearing strata under an extended area of some 360,000 square miles of territory, but the average flow and floods of the surface streams are recorded, and also the rainfalls in various districts have been tabulated and charted for a period of some thirty years.

A perusal of these reports gives ample evidence of how much can be attained in the matter of general knowledge to guide in the development of the water supply of a country, at comparatively small governmental expense, by persistent and conscientious record taking wherever opportunity presents itself.

By reference to the map accompanying each report, which shows the location and character of all the known artesian bores to date, it can be noted how few of these are government wells and what a large majority are those of private enterprise.

The investigation made, and the practical work done at public expense, seems to be well calculated to be in such location as to furnish the key to the general hydraulic conditions.

It is interesting to note in the 16th Annual report at the end of appendix No. 7, or table of bores, that the total number of feet bored in search of artesian water or minerals in Queensland, as far as ascertained up to June, 1900, was 976,711 feet, or 184 98 miles

These tables of bores, which appear for the years 1897 to 1900, inclusive, are replete with general information, giving in each case the water analyses, depth of bore, depth to principle water bed, temperature of water, static head above mean sea level, continuous flow when uncontrolled static, pressure at surface, etc. The analyses show a greatly varying quantity of solids, ranging from 6 to over 1200 grains per gallon, but a general average would not be far from 30 or 40. The temperature also varies through quite a range of degrees Fahrenheit, reaching 196 degrees at Dagworth Run, with a general average quite a little above 100 degrees. These tables are supplemented with many well executed charts, to which they refer

In the 13th Annual much is said relative to loss due to lack of proper legal regulation of all that pertains to the boring and casing of wells and general waste. In this connection Mr. Henderson quotes at length from the laws of the state of Colorado, U. S. A., an act to regulate the use of artesian wells and to prevent the waste of subterranean waters.

The 14th Annual gives considerable attention to the proposed improvements of the Brisbane River, and generally there is much said about the water supplies of Brisbane and other communities, whether the supply be artesian or natural.

The 15th and 16th Annuals include comprehensive maps showing the isopotential lines of artesian pressure. These charts supplement such information as is given regarding the power possibilities. T. C. I.

**Power Transmitted by Electricity, and Applied by the Electric Motor,** Including Electric Railway Construction. By Philip Atkinson. Third edition, 1900. D. Van Nostrand Company, New York. $5\frac{1}{4}$ x $7\frac{1}{2}$ inches, 241 pages, including index, and containing many illustrations. Price, $2.00.

This book has a fairly complete outline of the elementary principles governing direct current apparatus and transmission, but it is far from being up to date, even at the time of its publication. Under the title given, one would naturally look for some data on electrical transmission in factories, which is now being extensively installed to replace the old line shaft, pulley and belt systems, but scarcely a reference is made to the considerations involved in this important branch of electrical construction.

The chapter on "Electric Railways and Railway Motors" abounds in catalogue cuts of more or less obsolete trolleys, hangers and other appliances, but there is no mention whatever of the power required to move cars of various weights, or of the relation of generator capacity to car-miles of travel, nor is there even a paragraph on feeder arrangement, which is obviously one of the most important considerations in "transmitting" electric power.

There is a fairly extensive elementary description of the first types of alternating current motors, but scarcely a line on their more modern accessories, such as compensating coils and variable speed regulators, nor on the wiring and transformer connections for the *transmission* of alternating current.

In the chapter on Central Stations there does not seem to be much excuse for devoting several pages to the description of a station which, as is stated, has been put out of service some years since and superseded by a more modern equipment in another location. Several minor plants are described in a brief manner, but there is nothing in regard to their fuel handling, condenser systems or such important operative factors, nor is there any data on the cost of operation.

The subject of Mr. Atkinson's book is very comprehensive, and the advancement of electrical science is so rapid that it is impossible to cover such a field in the 200 small pages. The book will be of some value to readers who wish to get at the elementary principles of electrical work and their first applications.

W. S. M.

# WESTERN SOCIETY OF ENGINEERS

Secretary's Office, Library, Reading Room and Meeting Room
1734-41 Monadnock Block, Chicago

## LIST OF OFFICERS FOR 1902

| | |
|---|---|
| President | W. H. Finley |
| First Vice-President | Ralph Modjeski |
| Second Vice-President | Prof. L. P. Breckenridge |
| Treasurer | J. C. Whitridge |

## TRUSTEES

| | |
|---|---|
| B. J. Arnold | Term expires January, 1903 |
| C. W. Hotchkiss | Term expires January, 1904 |
| J. W. Alvord | Term expires January, 1905 |

**The above named officers of the Society constitute its Board of Direction**

Secretary and Librarian
J. H. WARDER

## COMMITTEES

*On Finance*—Ralph Modjeski, J. C. Whitridge, Andrews Allen.
*On Publication*—T. W. Snow, F. H. Bainbridge, Prof. L. P. Breckenridge.
*On Membership*—C. W. Hotchkiss, C. L. Strobel, Wm. M. Hughes.
*On Library*—J. W. Alvord, B. J. Arnold, Benj. Wolhaupter.
*On Entertainment*—W. J. Karner, C. W. Melcher, J. H. Spengler.

## MEETINGS.

Annual Meeting—The first Tuesday evening after the 1st day of January.

Regular Meetings—1st Wednesday evening of each month except January, July and August.

Special Meetings—3d Wednesday evening of each month except July and August.

Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

## NOTICE

From the dues of each member $2.00 is set aside as a subscription to the Journal.

Journal of the
Western Society of Engineers.

VOL. VII. APRIL, 1902. NO. 2.

## CXLII.

## SEWAGE PURIFICATION PLANTS.*

John W. Alvord, M. W. S. E.

*Read February 5, 1902.*

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### CORRECTION.

On page 235, the first word of the line below the picture should be Ferreous, not Ferons.

On page 237, second paragraph, eighth line, second word, should be spelled ferreous.

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ot only the sanitary engineer, but also the medical profession, the chemist, the bacteriologist and the municipal expert. The result of this has been that the language of this specialty has become replete with technical terms, drawn from these various professions, which cause it to be sometimes rather unintelligible. Moreover, as is the case with every art which is in a rapid state of advancement, new theories are constantly being propounded, so that the observer is often perplexed in his attempt to decide just how much of the art is safely or surely determined, and just how much is still in a theoretical stage.

Sewage purification plants labor under the difficulty that skilled expert supervision is fully as necessary in their operation as in their

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Note. After the presentation of the paper, Mr. Alvord informally described about sixty stereopticon views of Sewage Purification Plants, completed or under construction, only a portion of which are here represented with brief description.

# WESTERN SOCIETY OF ENGINEERS

SECRETARY'S OFFICE, LIBRARY, READING ROOM AND MEETING ROOM
1734-41 Monadnock Block, Chicago

## LIST OF OFFICERS FOR 1902

President.................................W. H. FINLEY
First Vice-President.................RALPH MODJESKI
Second Vice-President......PROF. L. P. BRECKENRIDGE
Treasurer..............................J. C. WHITRIDGE

## TRUSTEES

B. J. ARNOLD...........
C. W. HOTCHKISS.......
J. W. ALVORD..........

The above named

*On Finance*—Ralph
*On Publication*—T.
*On Membership*—C. V
*On Library*—J. W. Alvo
*On Entertainment*—W. J. Karner, C. W. Melcher, J. H. Spengler.

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VOL. VII. APRIL, 1902. NO. 2.

## CXLII.

### SEWAGE PURIFICATION PLANTS.*

John W. Alvord, M. W. S. E.

*Read February 5, 1902.*

The literature of sewage purification contains very much that is theoretical rather than practical. It also contains a good deal that has emanated from the laboratory rather than from actual practice. We have elaborate reports by eminent commissions upon miniature experimental plants, and the subject loaded with the literature of proprietary claims and patented processes, the authors of which are quite lawless as to exact statement of fact. These reasons have rendered it very difficult for the student or layman to form any adequate conception of the advancement in this branch of engineering.

Added to the difficulties above enumerated, of recent years there has been a remarkable advancement in our understanding of primary principles involved. An advance which has rendered necessary the revisions of many excellent and well written volumes upon this subject by eminent authors, and published as recently as within four or five years.

The subject of purification of sewage has interested not only the sanitary engineer, but also the medical profession, the chemist, the bacteriologist and the municipal expert. The result of this has been that the language of this specialty has become replete with technical terms, drawn from these various professions, which cause it to be sometimes rather unintelligible. Moreover, as is the case with every art which is in a rapid state of advancement, new theories are constantly being propounded, so that the observer is often perplexed in his attempt to decide just how much of the art is safely or surely determined, and just how much is still in a theoretical stage.

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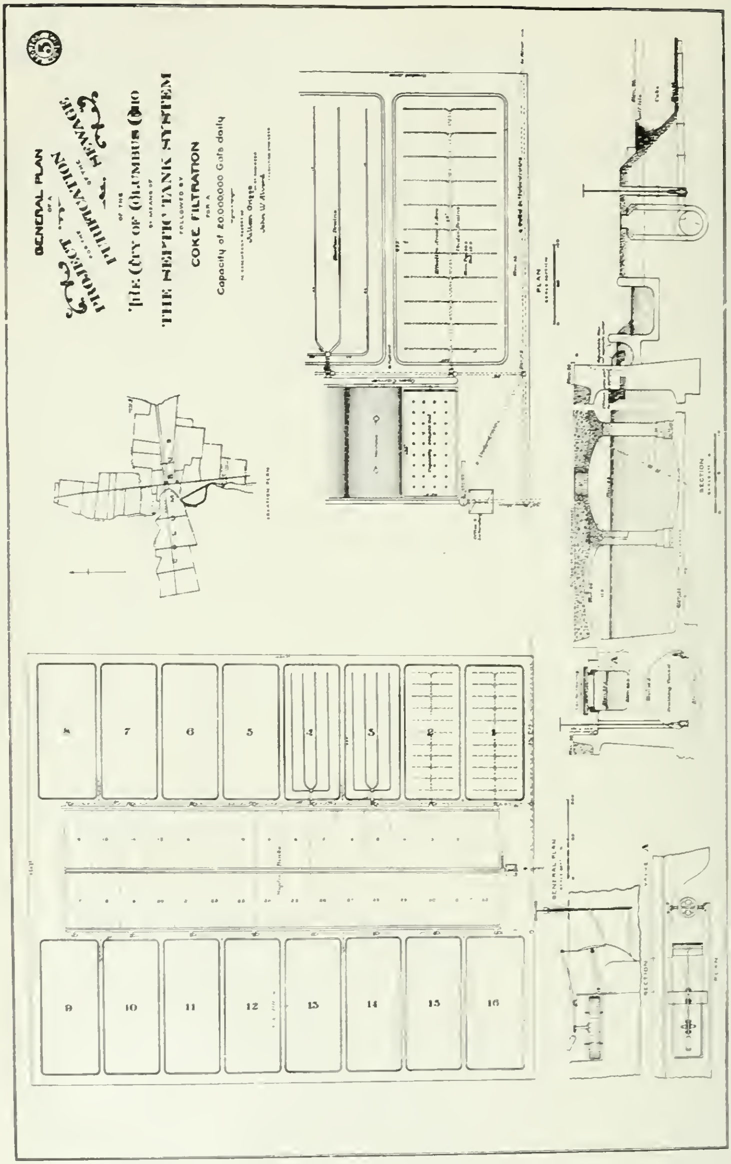


Original design of 32 Septic Tanks for Columbus, Ohio, in 1898, following closely English practice. Automatic control obtained by regulating device in combination with use of varying numbers of tanks.

design and construction. This is a condition that has not been recognized by the public at large and is only beginning to be apprehended by sanitary engineers themselves. Sewage purification works return no revenue for the investment, and therefore do not enjoy the popularity for municipal purposes that a good paying water works plant always does. It is but natural, therefore, that those municipalities that have been driven to adopt such plants, either by due process of law or by threats of legal proceedings, find themselves unwilling or unable to properly maintain the works after they are constructed. And after a few years, during which the expenses of operation are cut down again and again, the plant naturally fails to give the expected results and as a consequence is condemned as inefficient in design. Especially was this the case in former years when the expenses of operation were so very great. The newer and more recent biological processes, connected with automatic operating devices, it is hoped will somewhat escape this difficulty. Still it is true, so far, that the necessity for skilled supervision is not yet obviated.

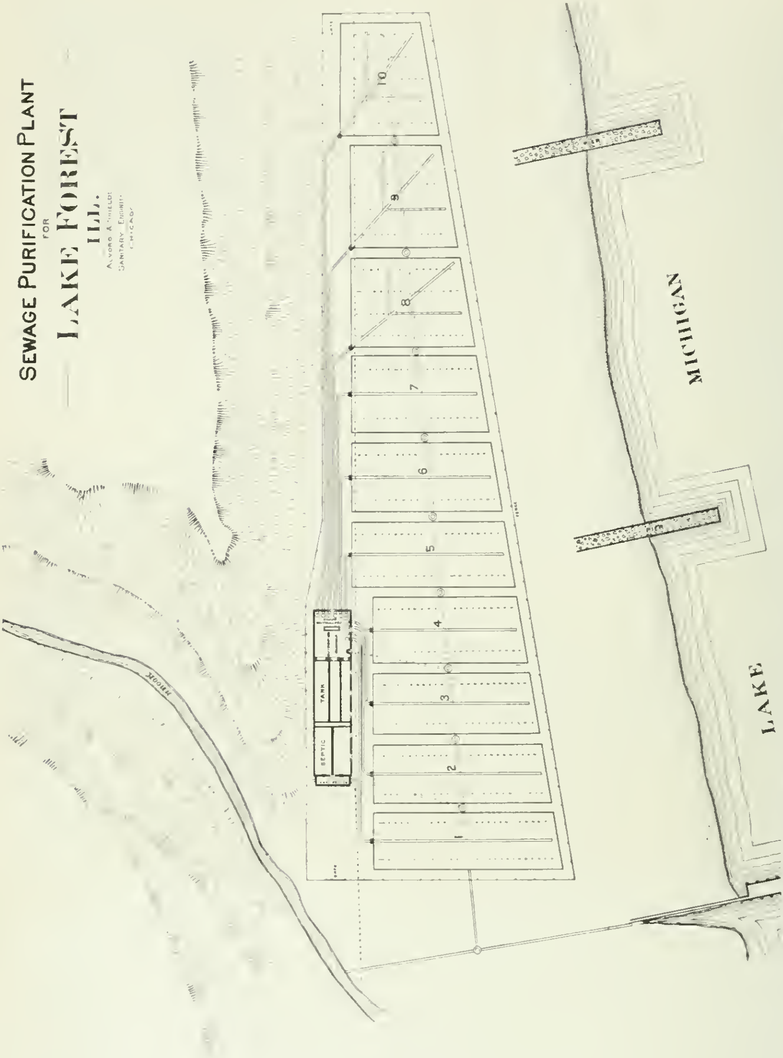
### PRINCIPLES INVOLVED IN PRESENT PRACTICE.

The purification of sewage as now practiced most sucessfully requires that the process be divided into two stages:

In the first stage there is the necessity of eliminating all of the greater portion of the particles of suspended organic matter contained in the liquid. This is accomplished more or less successfully by screening, sedimentation, chemical purification, roughing filters, bacteria beds and the septic tank. At the present time the septic tank is generally considered to be the most economical and efficient means of accomplishing the first stage of purification.

The second stage of purification consists of removing the more finely suspended residue and the impurities in solution. There are many ways of accomplishing this, known by different names, but the general principle underlying them all is that the liquid to be purified must be brought into contact by wide diffusion at innumerable points with certain forms of nitrifying bacteria in the presence of a sufficient supply of oxygen and retained under such conditions a proper length of time for complete chemical change to be accomplished; this properly done, the liquid is found to be purified. Most of the methods by which this principle is practically applied involve intermittency of application of the liquid to the filter and its alternating areation. This second stage involves processes commonly known as broad irrigation, intermittent filtration, bacterial contact beds, filters with forced areation and continuous filters.

Sewage purification has had its origin and greatest development in England, where crowded populations located on insufficient water sheds gave rise to an incredible nuisance which would seem intolerable in our own country. England has for forty years past wrestled with the sewage problem, and it is safe to say that over one-half of the sewage of the United Kingdom today passes through



Septic Tank treatment, followed by intermittent filtrations on Lake Shore sand found *in situ*. In operation since January 1, 1902. Capacity, about 250,000 gallons of sewage per day.

some form of attempted purification. It is but natural that England should have kept in the lead in this problem, and its most interesting recent developments have found their greatest appreciation in that country.

### THE SEPTIC TANK.

Both in this country and in England in a number of instances reservoirs have been built prior to 1894 and operated as septic tanks without attracting general attention. The installation at

Exeter, England, in that year was the first plant to attract wide notice, although it is interesting to know that a member of this Society constructed a true septic tank at Urbana, in this state, simultaneously with the Exeter tank.

Broad patents have been issued to the promoters of English tanks in this country, covering the principle of light and air tight tanks with submerged inlet and outlet, but it is significant that the owners of these patents have never yet been willing to test their validity in court, and it is evident that should they do so, the claims of many prior installations might seriously vitiate their value. For this reason sanitary engineers are everywhere installing tanks of their own design. It has been shown quite clearly that neither the exclusion of light or air nor the submergence of the inlet or outlet is necessary for the development of successful septic action. Many engineers prefer a form where these requirements are entirely neglected as giving the most satisfactory results; the ferment or septic action appears to go on in such tanks quite rapidly and the suspended matters in the sewage are dissolved as in air and light tight tanks.

General view Intermittent filtration beds, Lake Forest Plant, ¾ of an acre. Rate of flow, 300,000 gallons per acre per day, and upward.

The septic tank is not a complete system of purification in itself; only under the most favorable circumstances does it give effluents which are inoffensive. Generally the average effluent is both offensive and liable to cause nuisance, but the process effects one great change in the sewage it breaks down the suspended matter, some of which disappears in the form of inoffensive gas, while another and larger portion is dissolved into solution. This is accomplished by a species of bacterial fermentation within the tank, and when the fermentation period is properly adjusted, and not too long prolonged, the effluent will be found tolerably free from suspended matter and in a condition when it is most easily oxidized by further filtration. The importance of this change in the character of the sewage from an economical standpoint is much greater than would be first perceived, for it is this first stage of purification that has always proved to be the most difficult one. Chemical precipitation, with all its expensive machinery, was invented for this purpose, but it does not accomplish what the septic tank accomplishes in that it leaves the sludge problem unsolved and provides an effluent so loaded with disinfectant that it is not easily oxidized. Intermittent filtration alone has found its greatest difficulty in dealing with the suspended matters carried in the raw sewage, which, if turned upon the beds without preliminary treatment, rapidly forms a film upon their surface; this impervious crust would very soon render them useless if not removed from time to time. The raking off of this surface film and disposing of it effectively, in order to keep the beds up to their rated capacity, has always caused the most serious expense connected with intermittent filtration, and although an efficient supervision should keep the beds well cleaned, it is evident that a large portion of the time

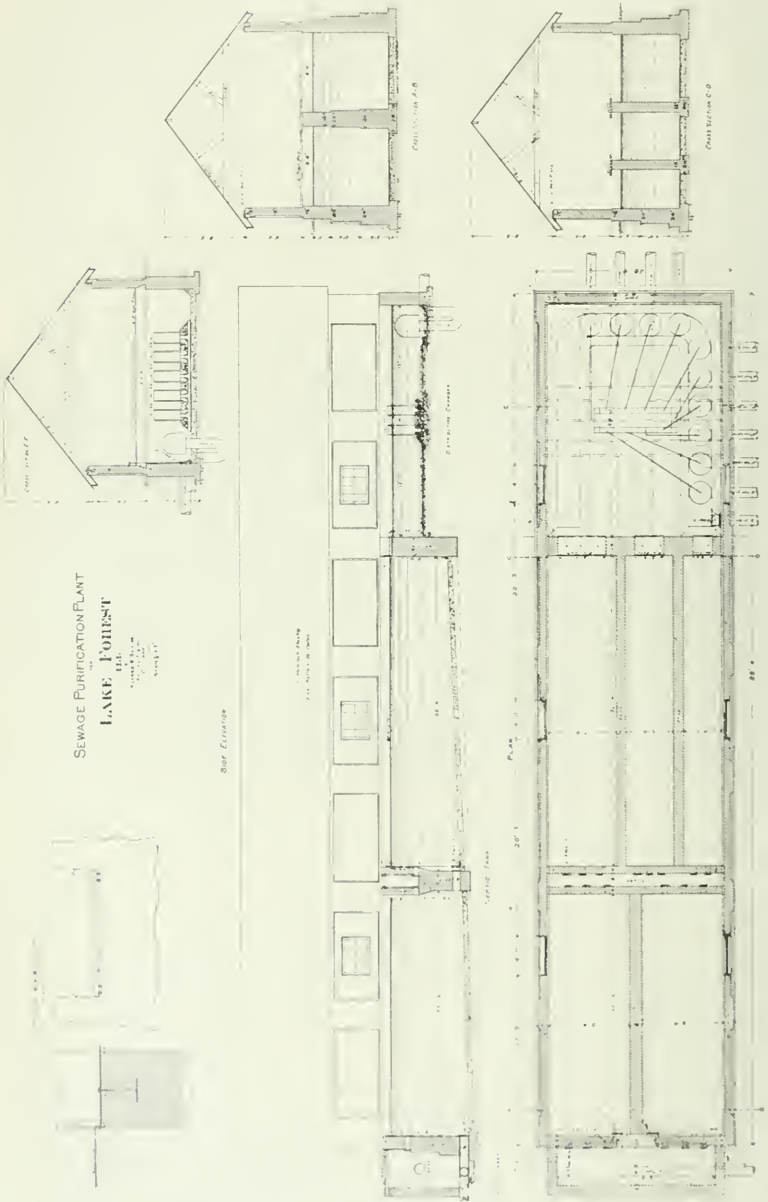
View of Tank Building and Filter beds, Lake Forest. 10 Filter beds, 3,200 sq. ft. each, receive a dose of about 8,000 gallons once in 10 or 12 hours.

their rate of filtration will only be a portion of full capacity of clean beds. This leads to the necessity for an increased area, which involves increased outlay.

Effluents from a septic tank which is doing its work properly may be delivered upon an intermittent filtration bed for many weeks at a time at high rates of flow, with apparently but the slightest clogging—allowing a very much smaller area of sand to accomplish the work than would be the case if the raw sewage were turned upon the beds direct. The same general fact may be said of broad irrigation, and it has been shown that bacteria beds are injured by having too large quantities of suspended matter passed upon them during long intervals of time. Effluents from septic tanks that are being properly worked seem to be very easily oxidized. The organic matter contained is largely in solution and in such a condition of instability that it is ready to break down into its constitutional gases without difficulty. Nitrification sets in promptly and the passage through a single intermittent sand filter will usually leave but one or two per cent of organic matter in the final effluent. The economy, therefore, of the septic tank is not alone that no expensive machinery is required, or a large amount of labor to perform its function; nor is it due entirely to the fact that it eliminates into harmless gases a large portion of the sludge left in it, but it is also essentially in the fact that it enables the effluent to be filtered at very high rates of flow through small areas of soil or compactly constructed contact beds occupying but little space.

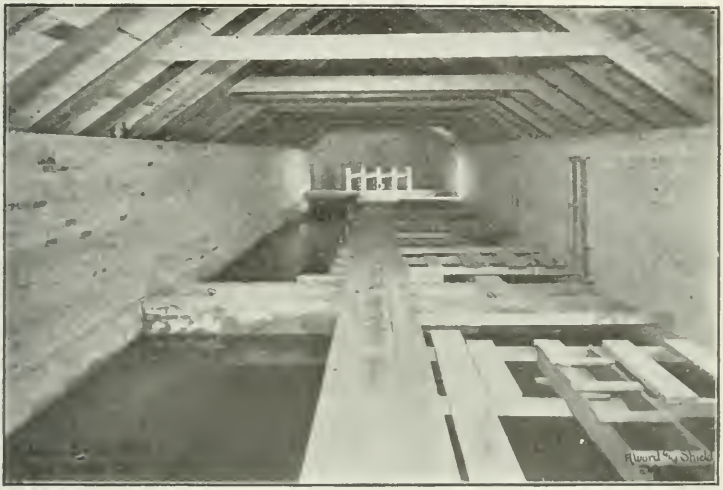
### NEW THEORY OF SEPTIC TANK CONTROL.

The septic tank has passed through the period of doubt and distrust and is now being carried along on the popular wave of enthusiasm. It has come to pass that almost any one thinks he can design such tanks, although he may only have read of them. Accepting the English dictum that the sewage should rest in the tank from 12 to 24 hours, many tanks in this country have been designed on this basis, ignoring the fact that English domestic sewage will often average about four times the strength of American sewage, and that the English climate is quite different from the climate in this country. The writer has found that septic tanks are not to be designed on haphazard principles, and has developed a theory from four years' practical experience in the operation of such tanks, that the particles of every sewage require a rest or fermentation period within the tank the length of time of which must be adapted to their temperature, their concentration, their character and the volume of flow. It has been clearly shown that if this fermentation period is unduly prolonged poisons are created which are detrimental to the life and activity of the anerobic bacteria. Such impairment of their vitality reduces their activity and fills the tank



Details Lake Forest Septic Tank, adjustment of fermentation period secured by five compartment system. Automatic distribution chamber included in building. Liquid capacity of tank about 60,000 gallons. Cost about $3,200.

with undecomposed suspended matter, which must be necessarily cleaned out quite often and produces an effluent which it is difficult to oxidize. On the other hand too short a fermentation period does not effect that degree of purification of the suspended matter which is possible and allows considerable suspended matter to be carried over onto the filters to their detriment, and also causes the tank to fill with sludge. The severe winter temperature of the northern states has been found to retard septic action, while the heat of summer accelerates it. This is a difficulty not so observable in England, where a warm, even climate prevails, and it is for this reason that we prefer housing our tanks with a light brick building covered by a felt roof which shall equalize the extremes of climate.

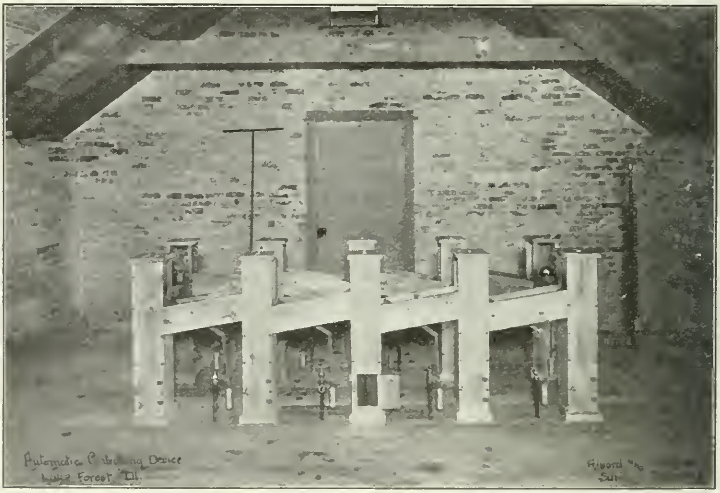


Interior of Septic Tank at Lake Forest. In foreground lateral trough for combining various compartments. In background automatic diversion chamber.

The theory of a proper fermentation period requires that some adjustment should be made between the volume of sewage flowing into the tank and the capacity of the tank itself. It is evident that a tank designed for the sewage of 2,500 people, and which receives the first year of its work the sewage from only 500 people, has its fermentation period prolonged many times more than its designer intended. It is evident, too, the strength of the sewage may be increasing as more and more house connections are made with the sewage system, so that from receiving a small quantity of thin, weak sewage when first put into operation, in the course of two or three years it may receive its maximum volume of strongly concentrated liquid. If now a winter of severe weather intervenes, retarding the septic action, and the alternating summer heats accelerate it, further complication ensues, and the perplexed public who begin, at times, to perceive an odor around the building and note that it has to be cleaned every month or so, lose faith in the original enthusiasm of its designer.

### EXPERIMENTS ON SEPTIC TANKS.

Early experiments with coloring matter showed that with wide or deep tanks the flow of sewage through the tank was more rapid through a certain defined zone, and that in this zone a portion of the sewage remained in the tank only about one-third of the time that would be denoted by the ratio of the volume of the sewage flowing daily, to the capacity of the tank. It was felt that this difficulty should be overcome so far as possible by more skillful design.



Lake Forest Plant. Automatic device for rotating contents of Diversion Chamber to filtration beds. Operation effected by rising and falling floats, a rolling ball and syphons operated by air valves.

The first tank our firm designed was proportioned for a 24-hour rest or fermentation period for the maximum flow of sewage, somewhat on the principle that one would load a gun so full of shot that something would get killed. The result was that with minimum flow an average fermentation period of over three days resulted, and the tank did not work well; probably portions of the suspended matters remained in the tank for weeks and it gradually filled.

After much study we temporarily partitioned off portions of the tank with a light wood partition of matched board in such a manner as both to reduced its effective capacity and prevent the direct flow from inlet to outlet, with marked improvement resulting. Again sections of the tank were partitioned off and the direct path of flow from inlet to outlet still further retarded. Finally a result was reached in which the septic action seemed to equal the rate of inflow of suspended matter, and this condition was maintained for some months until cold weather set in, when the tank began to slightly fill again. About this time Prof. Talbot called our attention to the fact that the fermentation was much more rapid in summer than in winter, and it began to be seen that adjustment in capacity for varying conditions must be provided for.

The problem of preventing the direct zone of flow between inlet and outlet presented the greatest difficulty in originating new designs, and experiments showed that no arrangement of baffle boards was wholly able to overcome this difficulty. The best results were found to be obtained when the entering flow was subdivided into several separate streams in parallel compartments. By this means the rates between the volume entering a given tank and its total capacity could be somewhat equalized.

## NEW DESIGN OF TANK.

In order to more thoroughly control the variations caused by increasing volume, temperature and concentration, a so-called elastic tank was designed for the City of Holland, Mich., having three long compartments which could be operated singly, in duplicate, or in triplicate, or continuously as one long tank. This form has proved to be capable of easy adjustment and well adapted to practical conditions, and in some of our more recent tanks five compartments of varying capacity have been introduced, which, when worked singly or in combination, allow almost any considerable fraction of the whole capacity to be utilized for the time being; this also equalizes the tendency for portions of the suspended matter to reach the outlet too early. The gates, troughs and chambers by which this manipulation is effected are simply and conveniently arranged, and render anything but skilled superintendence unnecessary.

In actual practice, it is believed that when a septic tank has its fermentation period properly adjusted to the strength, quantity and temperature of the sewage flowing into it, there will be a minimum deposit of undecomposed matter upon the bottom of the tank, unless cellulose or mineral matter is present in large quantities. If so, these should be removed by a preliminary chamber as much as possible. A great deal of misapprehension exists in regard to the

Septic Tank at Holland, Michigan, discharging effluent directly into Black Lake; built entirely of wood. Liquid Capacity, 60,000 gallons. Cost, $1,200. Completed in 1900. First tank using compartment system of control.

ability of a septic tank to consume the intercepted suspended matter. Statements are frequently heard that this is almost entirely consumed, and that the tank will proceed for years without any material increase in deposits. It may be possible that this is true in the case of a tank whose fermentation period is exactly adjusted and constantly watched, but so far as our experience has gone, and we now have some sixteen tanks in operation, the adjustment cannot be made so perfectly but that it is necessary to clean the tank at least once in a long while; therefore provision is made for flushing pipes from the bottom of the tank, by which excessive deposit can be removed.

It is believed that of the many tanks recently designed and constructed without apparent reference to the relation of capacity to flow, in some few of them happy accident has produced the right proportions. Such tanks are naturally pointed to with pride as being very successful, but as time goes by, if this theory is right, they may become unsuccessful through changes in volume, temperature or strength. In like manner some unsuccessful tanks may become successful ones. With the elastic tanks it is believed no such chances must be taken, and the designer, who should always superintend the operation of his plant for at least a year after it is put in operation, will be enabled by simply opening or closing a few valves to experiment for the first few weeks until he arrives at the proper fermentation period for the particular quantity or quality of sewage which he has in hand, and thereafter by equally simple manipulation keep it in successful operation without rapidly forming deposits or passing an undue amount of suspended matter to the filters. The septic tank in good working condition, and which is not being overcrowded, should have from four to eight inches of thick scum over its entire surface. There should be no objectionable odor perceived within the building when standing immediately on the compartments, and none at all outside the building. The effluent is rarely without some odor and in appearance will often be slightly clouded, but the proportion of suspended matter in it should not be large if the tank is working properly.

### CHEMICAL PRECIPITATION.

Of chemical purification, as a method of eliminating suspended matter in the first stage of sewage purification, it is sufficient to say that with the exception of a few rare cases it is already generally considered as out of date, as an economical and efficient process. Of the 19 chemical purification plants visited by the writer in England in 1888, only two could be properly called inoffensive and they were but recently built. Chemical purification has been humorously described by the late Col. Waring as "A method by which you buy chemicals and employ labor to mix them with the sewage, settle the sewage in expensive tanks, press the sludge thus ob-

Septic Tank at Danville, Ky., followed by intermittent subsoil filtration. Built in 1901. In operation since September, 1901.

tained in complicated machinery and after all have the sewage left on your hands, without having purified the water which originally contained it."

The writer has recently noticed an account of a chemical purification plant in England which was so offensive that legal proceedings were brought and judgment for damages obtained on account of the nuisance, by a land owner who resided five miles away from the plant.

The enormous expense of operating chemical purification renders it quite certain that at no distant day the largest portion of the plants of this character will be replaced by the septic tank, where the same work is accomplished with practically no operating expense. It is because of this fact that we see the present enthusiasm for the septic process.

## THE SECOND STAGE OF SEWAGE PURIFICATION.

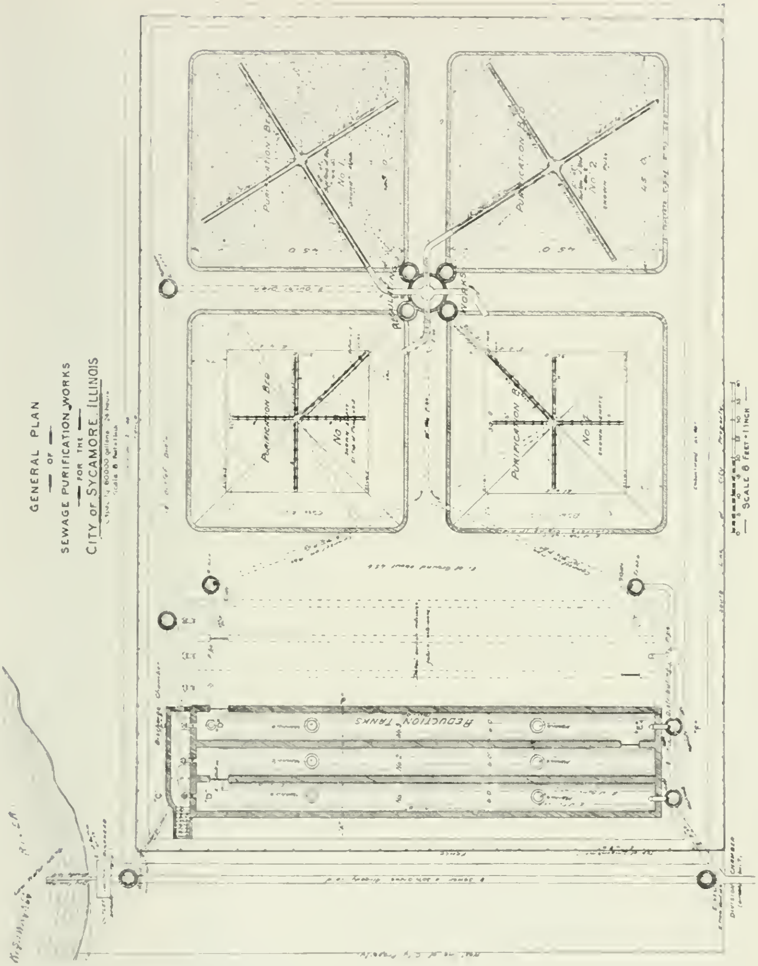
The second stage of sewage purification, by which the organic matter, which is largely in solution, is eliminated, is perhaps better understood in practice and presents less difficulties than does the first stage, already considered.

Broad irrigation and intermittent filtration have been known and practiced for many years and much data and information exist as to their details. Their chief difficulties have arisen from the accumulation of suspended matter upon the surface when the raw sewage was turned directly upon the land and the large areas required in consequence.

In England, where land near large cities is enormously expensive, they have endeavored for years to overcome this objection by improvements in chemical precipitation as a first stage, and attention was early attracted by the experiments of the Massachusetts State Board of Health, which showed the wonderful effectiveness of fine gravels in oxidizing the impurities of the sewage which dripped through it. As a result of further experiments along this line, sanitary engineers there developed the bacteria and contact bed as a method of consuming suspended matter as well as oxidizating organic matter in solution.

## CONTACT BEDS.

The early English experiments on contact beds were summarized by the writer in a paper presented to this Society in 1898. A contact bed, it may be explained, is a water tight tank filled with fine or coarse particled matter and into which the sewage is regularly filled, rests for a few hours full and is then emptied. An interval then ensues in which the air, drawn down into the body of the ,tank by the removal of the liquid, thoroughly permeates its interstices and



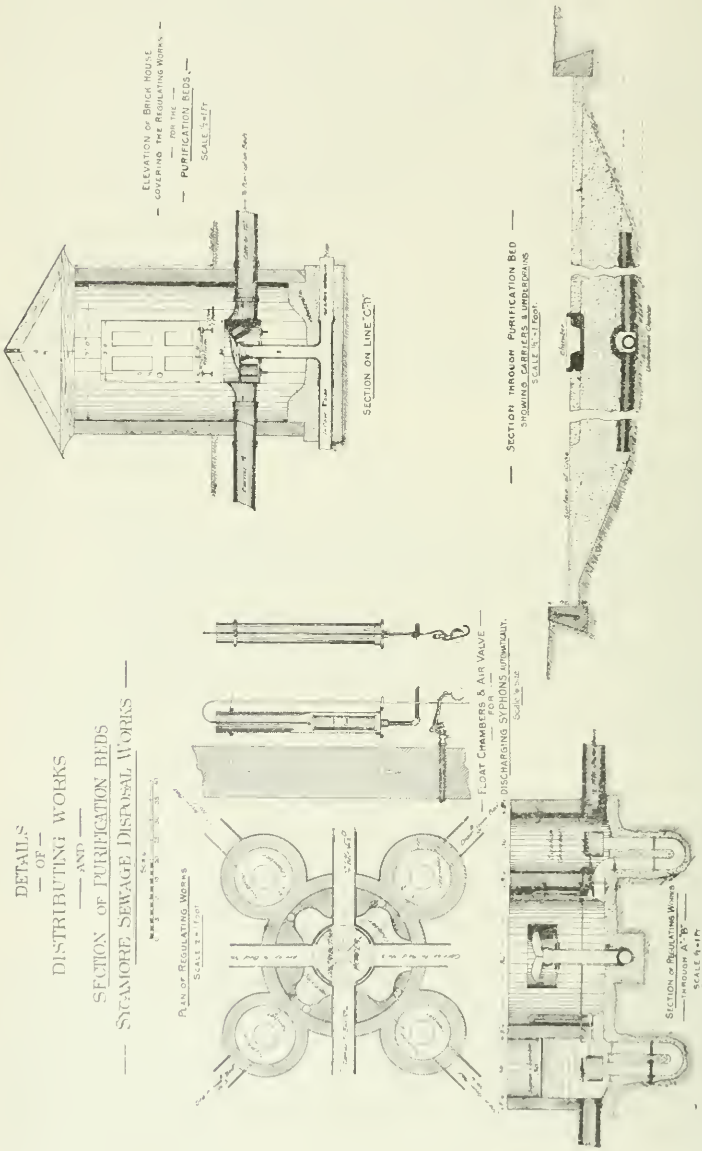
Plant for Purification by Septic Tank, followed by single contact beds of fine cinder. Septic Tank wholly below surface. Shows general arrangement of tank and distribution to beds through central chamber.

aerates it; the bacteria which swarm over every particle of the filter in the presence of such effective aeration oxidizes the organic impurities of each liquid dose as they successfully pass through the bed, and remove a large portion of the impurity.

A contact bed, as has been remarked by the writer elsewhere, resembles nothing else so much as a huge lung. The filling and emptying of the liquid in the contact bed corresponds to the inhaling and exhaling of a breath, and as the indrawn air in the lung oxidizes the impurities of the blood through the thin walls of its tissue, so does the entrained air and bacteria in the contact bed do its work upon the dissolved impurities in the sewage.

It has been found desirable where a high degree of purification is desired to follow one contact by a second contact in a bed of finer grain, emptying the contents of one bed into a second bed at lower grade, and if necessary the process can be repeated a third time.

Long continued trials of the coarser grain bacteria beds dosed


DETAILS
— OF —
DISTRIBUTING WORKS
— AND —
SECTION OF PURIFICATION BEDS
— SYCAMORE SEWAGE DISPOSAL WORKS —
PLAN OF REGULATING WORKS
ELEVATION OF BRICK HOUSE
— COVERING THE REGULATING WORKS —
— FOR THE —
— PURIFICATION BEDS. —
SCALE ¼"=1 FT
SECTION ON LINE "C-D"
— FLOAT CHAMBERS & AIR VALVE —
— FOR —
DISCHARGING SYPHONS AUTOMATICALLY.
— SECTION THROUGH PURIFICATION BED —
SHOWING CARRIERS & UNDERDRAINS
SCALE ⅛"=1 Foot.
SECTION OF REGULATING WORKS
— THROUGH A-B —
SCALE ¼"=1 FT

Details of Automatic Distribution for contact beds, where filling and emptying are both automatically controlled.

with raw sewage only partially screened as a first stage of purification, have given rise to the fear that they are liable to gradual clogging with suspended matter, and require to be cleaned or washed, and perhaps rehandled; that this is positively necessary in all cases has not yet been fully settled; but if it is found to be the case, it is a question as to whether the cost would not be much less than the expense of labor in raking intermittent filtration beds upon which the raw sewage is turned. The whole question of the best method of treating suspended matters as the first stage has been for the present settled in favor of the septic tank, as has been already shown, and the proper field of the contact bed is now deemed to be the second stage or the purification of matters in solution.

For the second stage, the contact method has undoubted advantages, especially where sufficient area of sand bed is not available for intermittent filtration. If sand beds for intermittent filtration have to be constructed, contact beds will almost always be found to be more economical. But if the sand is in place or nearly so and of the right grain, and land is not too dear, intermittent filtration will generally be found the least expensive. Contact beds occupy much less area for a given capacity than do sand beds for intermittent filtration, but being of water tight construction this advantage is sometimes overcome by this expense.

Properly operated, intermittent filtration will give high rate of purification, much more so than single contact beds, but double contact beds will do nearly as well as a single intermittent filtration through sand of the proper grain.

The degree of purification to be attained by any plant is always a matter of local consideration. In some cases it is only necessary to abate a nuisance, in others a water supply must be protected; either can be accomplished, but the latter requirements will cost more to attain than the former.

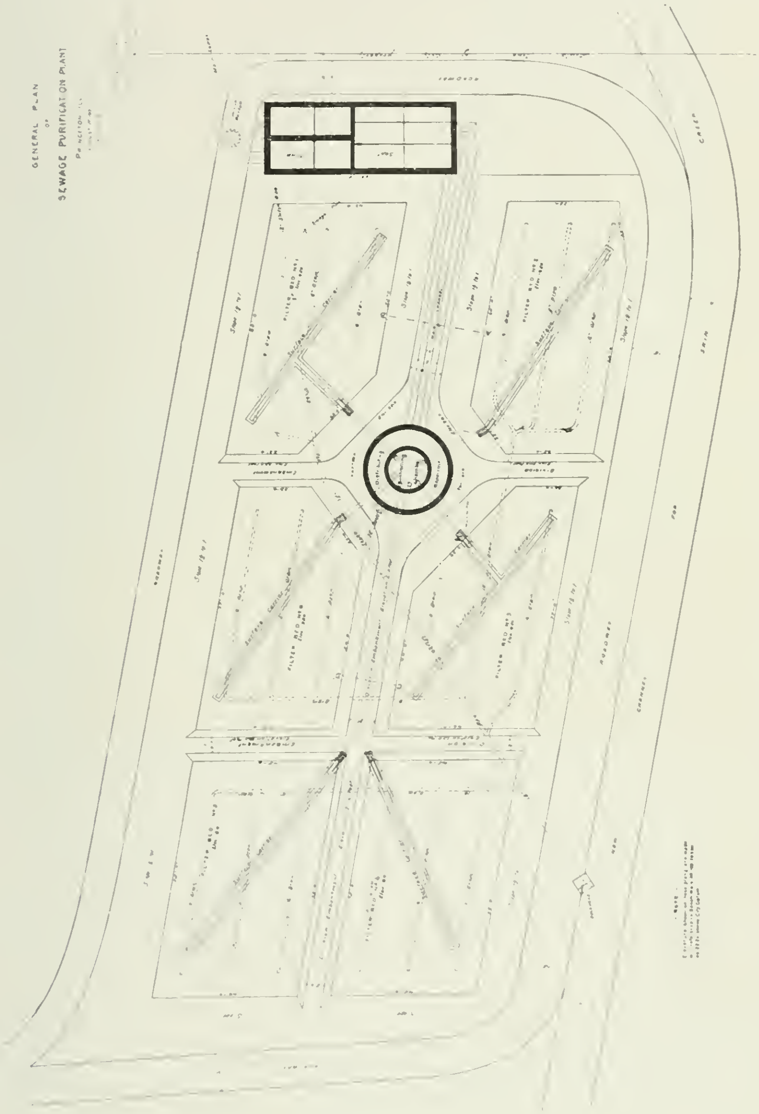
### AUTOMATIC CONTROLLING DEVICES.

With the advent of contact beds has come the necessity of automatic control of the filling and emptying period. The regulation contact beds have of necessity to be quite even and regular, and while the method of emptying and filling by hand has been adopted in some cases, automatic devices operated by the rise and fall of the liquid within the tank have become popular and a few have proved successful. There are several patent devices in England for this purpose and several in this country, some of which are being introduced at a number of places. These devices will undoubtedly work a great revolution in the care and management of sewage disposal plants. In intermittent filtration practice with raw sewage it has always been the custom, inasmuch as labor was necessary for raking off the beds, to utilize that labor in rotating the flow from one bed to another, but with the advent of the septic tank and the discontinuance of the frequent rakings has also come the demand for automatic control for rotating the flow, and this is as necessary in intermittent filtration as it is in single or double contact beds. With the successful introduction of such devices, diverting the flow from septic tanks to secondary treatment by filtration in rotation, sewage disposal plants have become well nigh automatic, requiring little or no ordinary labor, and a minimum of skilled supervision so far as time is concerned. Not only this, but automatic devices make intermittent filtration more efficient than ever before by reason of the regularity by which the process proceeds, and the independence which results from a disregard of certain fixed hours of labor. It is customary to operate contact beds with two hours resting full, thirty minutes to empty, three hours resting empty to aereate, and thirty minutes or so to fill, thus dividing the day into six-hour cycles and providing for four fillings per day. With strong sewage, eight-hour cycles and three fillings and emptyings per day are sometimes best. All this work may go on continuously with the automatic devices without regard to night or day, noon hour or work hour, fair weather or storm, and this regularity is found to be very desirable and essential to the economical workings of the plant, for by its

General view Septic Tank at Princeton, Ill.
Controlled by 5-compartment system. Liquid capacity, 60,000 gallons.
Cost, $3,500.

means the greatest possible effectiveness is obtained from any given contact bed or filter.

One of the plants designed by the writer's firm which was put in

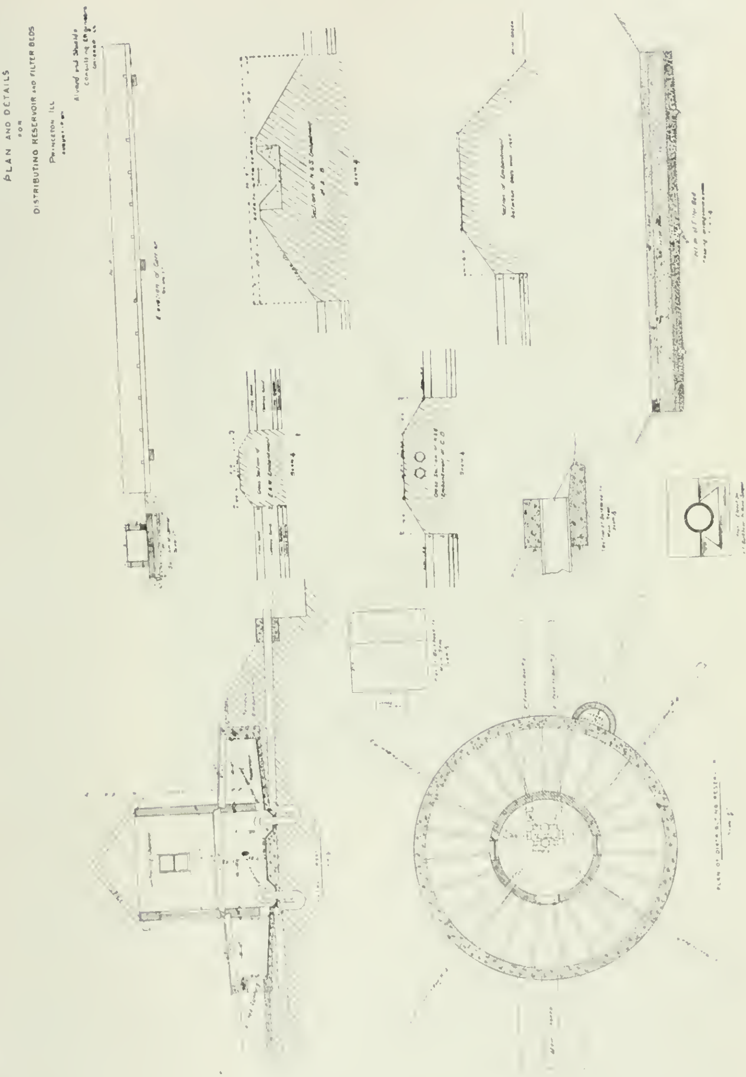


General arrangement of Plant at Princeton, Ill. Septic Tank followed by intermittent filtration with automatic distribution. Tank completed and put in operation November, 1901. Filtration beds not yet finished.

operation last summer has been working automatically ever since. It is visited for a few minutes twice each week to see that no malicious mischief has been done and that nothing is out of order. On such visits the attendant notes the temperature, quantity of sewage which has been purified since his last visit (obtained by reading a counter on the automatic device), and notes such other points as may be interesting or necessary in regard to the plant. It is believed from the past six months' experience that $100 per annum will cover the cost of maintenance of this plant, which is purifying the sewage of about 2,000 people.

### COMPARISON OF COST.

In order to fully appreciate some of the modifications which have been brought about in the filtering of septic tank effluents, it is necessary to remember that the Massachusetts State Board of Health experiments have shown that in order to filter raw sewage successfully upon fine sand beds, an acre of bed is necessary for each 16,000 to 20,000 gallons of sewage per day. With somewhat coarser sand from 30,000 to 40,000 gallons per day of raw sewage can be filtered, while with very coarse sand there is a possibility of passing from 100,000 to 150,000 gallons per day if the beds are kept well raked. With septic tank effluents where there is but little suspended matter to deal with, and the liquid is ripe for oxidization, even with quite fine sand at least 200,000 gallons per acre per day can be filtered, with coarser sand, 350,000 gallons would be a safe allowance; while with the coarsest and most desirable sand at least 500,000 gallons per acre per day is possible. The difference between these figures is this, that if you have a plant that must purify the sewage of 2,500 people by the older method of intermittent filtration alone, you would require (at 100 gallons per capita) not less than seven acres of sand bed for medium sized sand, and if the available sand was quite fine this would become 14 acres. If the sand had to be brought from any considerable distance the beds would cost complete not less than $10,000 per acre, or from $70,000 to $140,000 for the plant. Now, considering the substitution of the septic tank preliminary to the filtration, and you would at once reduce the cost for filtration area to about three-fourths of an acre, and you might easily afford the coarsest sand brought from a great distance for the beds, which even then could be worked at a rate not exceeding 300,000 gallons per acre per day, and the entire plant would cost not more than $16,000, including the septic tank. Compare this with the $70,000 to $140,000 mentioned before, and some of the enormous advantages of the later processes can be appreciated, especially in unfavorable localities. Not only in first cost, but also in operating expenses, simple intermittent filtration alone would cost at least twice if not three times greater than that necessary for the septic-tank installa-



Automatic Diversion Chamber at Princeton, Ill., rotating effluent from Septic Tank upon 6 Filter beds.

tion. Such a comparison as this I have just described is not at all uncommon, and is simply revolutionary in its results. It permits cities to own and operate sewage purification plants to whom it has been heretofore impossible. It allows plants to be built in localities where every advantage is lacking, and it permits the problem to be brought within workable limits for the largest cities of this country. In bacterial contact plants the results are still more favorable as to the rates of flow. With septic tanks effluents most of these contact bed plants are worked at the rate of 500,000 to 750 000 gallons per acre per day, with the same rates of reduced cost for maintenance, and it is questionable whether a rate of 1,000,000 gallons per acre per day for dilute American sewage is not fairly practicable.

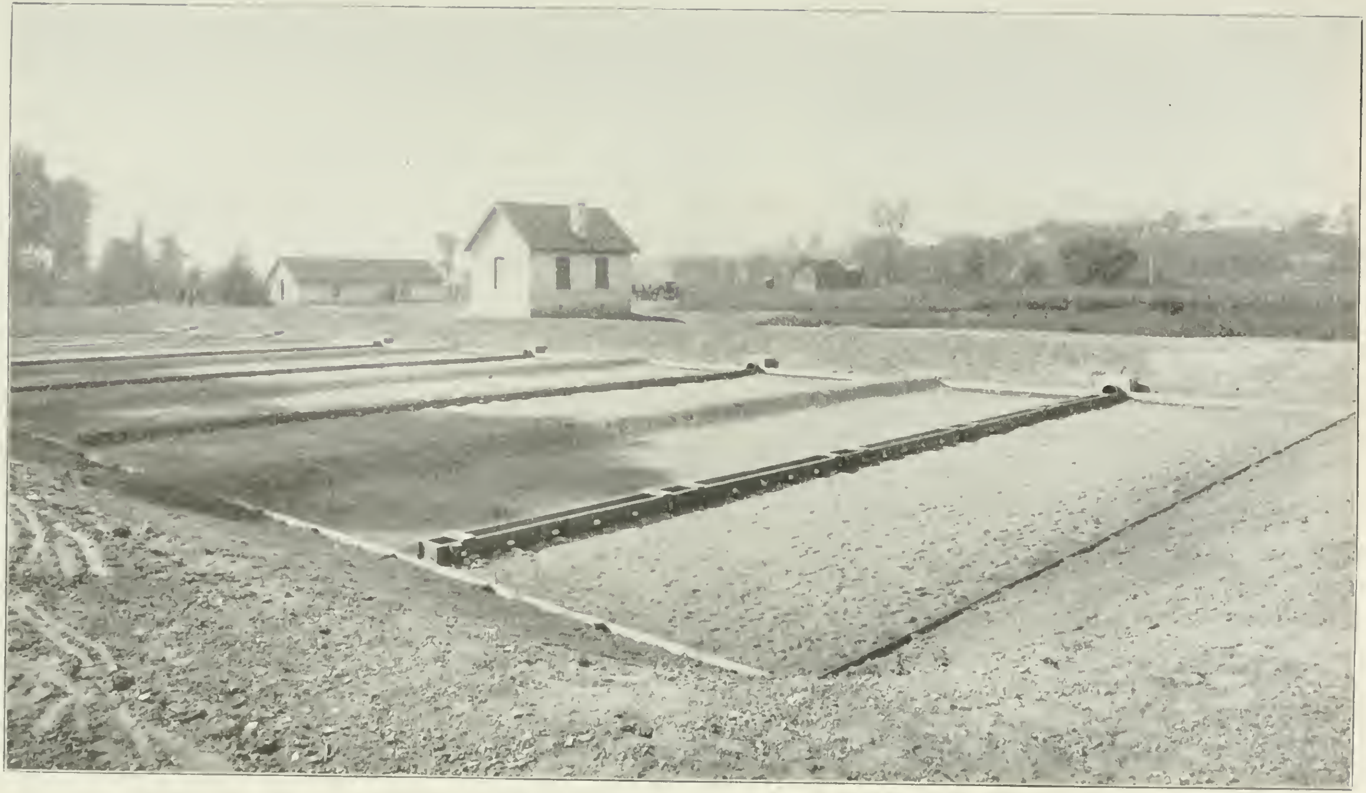
Interior of Septic Tank at Princeton, Ill., before admission of sewage. Initial compartment inlets and sludge valves.

Already the city of Manchester, England, has under way a project for the purification of the sewage on these new principles, costing $1,150,000. The city of Leeds will soon follow, and over 200 projects are on foot for cities of less population in England alone. We shall watch these experiments on so large a scale with unusual interest.

DISCUSSION.

*Mr. Finley*—How high are those beds at Lake Forest above Lake Michigan?

*Mr. Alvord*—The surfaces of the beds are about six feet above Lake Michigan, and of course they are thoroughly drained by a



General view of Plant at Wauwatosa, Wis., taking sewage from population of 3,000. Put in operation in August, 1901. Cost, about $6,000. Septic Tank followed by intermittent filtration with automatic distribution.

main underdrain, with numerous branches. One of the difficult problems of this site was to prevent the beds from being injured by the wind blowing along the beach, which tends to fill the beds with fine sand, so that they become flooded. We are constructing a very high board fence, which we think will prevent this trouble.

*Mr. Francis H. Bainbridge*—I would like to ask Mr. Alvord if these sand beds ever have to be cleaned or replaced when used for filtering purposes?

*Mr. Alvord*—They may have to be surface cleaned, but not replaced. So far as intermittent filtration has been known and practiced for the last dozen or fifteen years, there has been found to be no necessity for replacing the sand of the beds. There is necessity, however, of loosening the surface once in a while, which is generally done by raking off and and removing the surface flake or crust, if any; with the septic tank effluent the raking has become very much less burdensome.

*Mr. Finley*—Mr. Alvord, I believe you said that the plant for Princeton cost $3,000, with a population of 4,000. What is the cost of the maintenance of that plant?

*Mr. Alvord*—The filter beds have not yet been constructed in that plant, and of course we do not know what the maintenance would be. In our Wauwatosa plant, judging from the run which it has had so far, we think $100 a year would be a very ample figure to estimate on, and that is providing for the sewage of about 2,000 people. The first cost of that plant was a little over $5,000. The first cost of the Lake Forest plant was $8,000. The total cost of the Princeton plant, when it is completed, will be about $6,500.

*Mr. Torrance*—What happens to those sand filters during the winter months? For instance, such weather as we had yesterday.

*Mr. Alvord*—Sewage in process of dissolution is undergoing a chemical change, which gives rise to heat, and that heat is thrown out into the sand beds. It is generally sufficient to melt them if they are already frozen. It keeps the interior of the septic tanks quite warm. In fact, the men completing our Lake Forest plant were accustomed to eat their lunches in the septic tank, after it was in operation, that being the warmest place they could get. The Lake Forest beds were quite well frozen before the sewage was turned onto them, but after a very few days the main part of the frost, which perhaps was two feet thick, disappeared. The tendency is for a light crust of ice or snow to form on the top of the beds, but underneath that crust the filling and soaking-in process is going on all the time, even through the very severely cold weather.

*Prof. A. N. Talbot*—I have been very much interested in Mr.

View of construction of Septic Tank at Wauwatosa, Wis
Framing of forms for concrete work.

Alvord's presentation of the details of the purification plants which he has constructed, and he has certainly had very valuable experience and has constructed very successful plants. As he has stated, many changes in ideas concerning methods of purification have been made in the past few years, and while a great deal has been learned concerning the processes of purification, many matters remain unknown or are yet in dispute. It would not be strange, then, if I should differ with Mr. Alvord in regard to some details of the methods to be used in such purification or in the explanation of the action of processes, and of the principles involved in this purification. However, it does not seem best to take up this matter at this time. It seems, though, that the question of the use of terms to be employed might be discussed a little. In a subject as new as this it is not strange that there should be differences in the use of terms, and it is well to attempt to start a usage which will be systematic and not misleading.

It has seemed to me wise to confine the use of the term "contact bed" to those beds in which there is aerobic action in the purification of the sewage; that is, to those beds in which air is freely admitted and in which the sewage has been sufficiently cleared of organic matter in suspension to permit this aerobic action to take place. In a paper given by Mr. Alvord a number of years ago, the coarse bacteria bed was described. These beds were filled and emptied in much the same way as the ordinary contact bed, except that raw sewage (still holding the suspended organic matter) was applied. Between the time of emptying and filling, little opportunity was given for air to reach the interior, as the retained organic matter and organic growth prevented easy access, and this and the quick consumption of the oxygen reaching the interior formed conditions which made the bacterial action mainly anaerobic. There was then little effect on the matter in solution, and the effect was similar to septic action. I think such a bed should retain the name "coarse bacteria bed," and that the term "contact bed" should be confined strictly to what was formerly known as fine bacteria beds. The contact bed, then, takes sewage from which most of the suspended matter has been removed by some process and acts upon the finely divided matter and upon that in solution. Its action is mainly aerobic. In this connection it may be said that it seems to me that the purifying action of such beds is mainly during the time in which the sewage is held in the bed.

Construction of Intermittent Filter Beds at Wauwatosa, Wis.
First layer of gravel being spread around underdrains.

In passing it may be added that coarse bacteria beds which were in operation at Sutton, England, and experimental beds at Manchester and Leeds have proved to be not very successful, as they became clogged and had to be cleaned.

In the same way with intermittent filtration. It seems to me the term "intermittent filtration" of sewage should be used for that process where the sewage is applied intermittently and is distributed throughout the depth of the bed without at any time completely filling it.

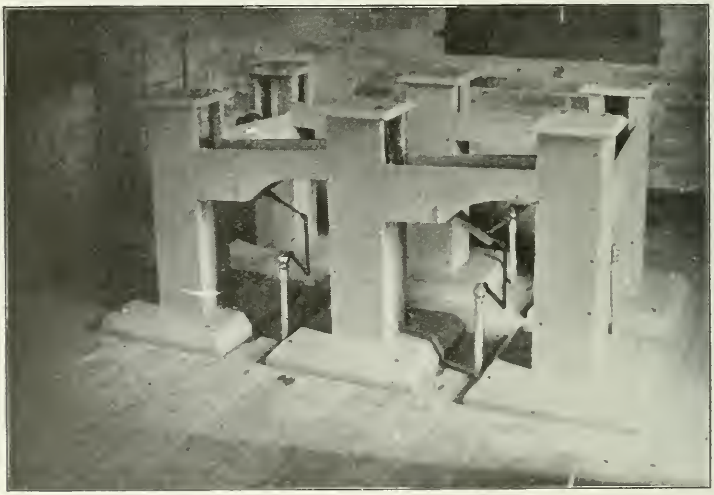
As Mr. Alvord knows, I have also objected to the term "fermentation" or "rest period" in describing the capacity of septic tanks. The term is misleading in that one is likely to think that the sewage actually remains in the tank during the time indicated. Of course the matter in solution, the liquid which passes through, is changed to no great extent in the passage through the tank. As stated in the paper given before this Society some time ago, it seems to me that the capacity of these tanks is limited or governed by the area of the surface, and by the time taken to change the organic matter in suspension which is left behind in the septic tank. That is to say, if the flow through the tank is slow enough, there will be a subsidence or sedimentation which may be sufficient to retain the suspended matter, even with a relatively considerable flow, but this retained suspended matter must be allowed considerable time for the operation of the bacteria, and if this exposed surface becomes coated over by other organic matter before the bacterial action is well under way, as would be the case where the tank is too small, the effective action of the tank would be reduced, and the tank would fill up rapidly. To avoid a possible misconception of terms like "fermentation" or "rest period," the capacity of the tank may be expressed in terms of the number of hours' flow of sewage, as, for example, a tank of cubic capacity equal to eight hours' flow of sewage.

Construction of Automatic Diversion Chamber at Wauwatosa, Wis.
Setting the syphons in the bottom of the chamber.
Each bed has an independent syphon and connection.

Concerning elastic tanks, it should be stated that the size of tank may vary within considerable limits without seeming to affect the effluent. For example, experiments made in Leeds, Eng.—not laboratory tests, but on tanks of 250,000 gallons capacity—showed very little difference in results obtained with tank capacities of twelve hours, twenty-four hours, and forty-eight hours' flow of sewage. This of course was strong sewage.

*Mr. Finley*—This question of sewage purification being in such a condition of evolution, I have wondered whether it is a good investment for a village to spend very much money on these systems.

*Mr. Bainbridge*—If they do not spend the money, then there will be no further evolution.



Automatic Ball Controlled Device operating six intermittent filtration beds at Wauwatosa, Wis. Has been in successful operation since September, 1901.

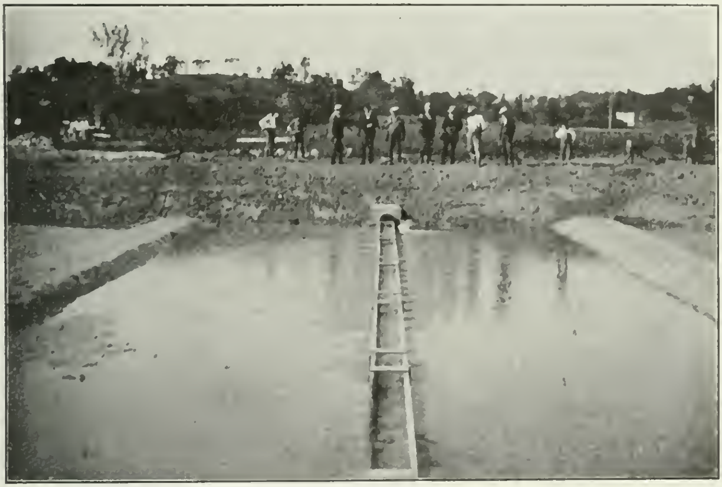
*Mr. Potter*—It seems to me the best thing to do is to adopt the best method now available and then when improvements are made, incorporate them later. Most villages are compelled to take some action by the existence of serious nuisance, and often they are driven into it, by threats of legal proceedings.

*Mr. Finley*—If I remember rightly, the City of Madison put in some arrangement for the treatment of sewage which was not very successful.

*Mr. Alvord*—They let a contract to a proprietary company for a chemical purification plant, with a guarantee, which was not successful, but have substituted for it a septic tank with contact beds designed by a competent sanitary engineer, which I think is doing very well.

*Mr. C. D. Hill*—What would the effect be to lose the matte that forms on the surface of the tank, by removal of the baffle boards?

*Mr. Alvord*—Our observation has been that baffle boards are not absolutely necessary and that the matte will stay there, even without them, and in so far as it is a question of whether it brings conflict with any patent claims, we have decided, in one of our plants, to leave the baffle boards out temporarily. We do not always do that, but we did in this case.



Distribution of Septic Tank effluent upon intermittent filtration beds, at Wauwatosa, Wis. View taken 4 minutes after discharge in diversion chamber. Dose, 6,000 gallons.

*Mr. Bainbridge*—What is the action of the matte in the septic tank?

*Mr. Alvord*—There forms on top of the tank a scum, which consists of the residue from the suspended matte in the sewage. The particles of organic matter as they enter the tank are attacked by the bacteria in the tank and certain gases are liberated from them; this causes the particles to rise to the top, or, if the gases are not liberated with sufficient rapidity, they may drop to the bottom, and either at the top or bottom the remains of these suspended particles, consisting of the more refractory portions, together with fibrous and cellulose matter which are undergoing this process of dissolution, form a coat of matter, and, as Prof. Talbot has pointed out, it is desirable that there should be a large surface, so that these particles may be as thoroughly dissolved as possible before they become covered by other particles.

With reference to the Professor's allusions to our different ideas about the "fermentation period," I may say that it seems to me it is largely a distinction without a serious difference. As I understand it, he thinks the area of this matte and the size of the tank are the vital questions—that they should be sufficiently ample so that the suspended matter should not cover them too rapidly, while my idea is that the particles of suspended matter entering the tank must remain within the tank a period which I term the "fermentation period," during which they must be dissolved into their constituent gases or reduced into solution. I do not see very much difference, myself, between the two theories, but if there is any, we will have to work it out together.

*Prof. Talbot*—I did not intend to attach any special importance to the calculation of this area, especially as with the usual depth of tank its capacity will be proportional to this area. As Mr. Alvord has just expressed himself, I should want to express myself as not agreeing that the time period of the passage of the sewage through the tank is equal to the actual period of fermentation. In fact, I have shut off the flow entirely from an overdosed septic tank in order to get rid of accumulated organic matter, and after a week have found the condition of the tank materially different from what it was at the beginning. Evidently the period of passing through the tank may not be the period required for bacterial reduction. My objection to the use of the term is that it may lead one to suppose that this period is the time which the sewage remains in the tank, and that it is identical with the fermentation period.

*Mr. Finley*—Would it not be the case that a small tank, which we will say takes a large volume of flow, would naturally fill with these undecomposed particles of suspended matter, while a tank which might be very ample in capacity would not be satisfactory?

*Prof. Talbot*—It is not a question whether enough area or capacity is being used, but what term should be used to describe the ratio between the capacity of the tank and the number of hours' flow of the sewage going through the tank.

*Mr. Alvord*—We have been driven into this theory largely because tanks which seemed to be too small filled up, and also tanks which seemed to be too large filled up. By partitioning off those tanks which were too large we get a capacity from which the surface matte remains only four or five inches thick. There is no further accumulation. Now there seems to be an adjustment here between the amount of particles which entered with the flow and were fermented and the capacity of the tank, and I have unfortunately selected "fermentation period" as describing that ratio. May I ask the professor what term he would prefer?

*Prof. Talbot*—Let me say first that I am not disagreeing with Mr. Alvord's statement that a suitable size of tank should be used. I have no term to propose other than to state the capacity of the tank in terms of the number of hours' flow, viz.: instead of eight hours of "rest period" or "fermentation period," use "the cubic capacity of the tank equals eight hours' flow of sewage."

*Mr. W. G. Potter* (*by letter*)—In the discussion of Mr. Alvord's paper on Sewage Purification, the question of the effect of cold weather upon the septic method of purification, and of possible freezing of the liquid, was touched upon.

In regard to the latter point I wish to submit the following:

It is a fact self evident to all that chemical action of any kind developes or causes heat. Chemical action of course is progressing in the septic tank, in the contact beds and in the sand beds, and experiments show that the heat produced in the septic action is sufficient to keep the temperature throughout about the same and is often sufficient to raise the temperature of the effluent higher than the original sewage.

In the report of the Massachusetts State Board of Health for 1898 in coke filter bed No. 103, which was used for the full twelve months, the entering sewage had an average temperature of 58 degrees and the effluent 59 degrees.

In sand bed No. 116 of same report, the use of the bed was begun in September, with a loss of temperature for several weeks while nitrification was not in full operation, but the whole period from September to January showed a gain of 1 degree in temperature.

In 1899 report of same authorities in septic tank with the record of ten months from March 1st to January 1st, the temperature showed an average gain of 1.2 degrees for the entire period. The lowest monthly average temperature of original sewage was 46 degrees, while the lowest for septic tank effluent was 48 degrees Fah.

In 1900 report the septic tank again shows a gain of 1 degree for the yearly average, the lowest average temperature (for any one month) of original sewage being 39 degrees in February and December, with temperature of effluent raised to 43 degrees and 47 degrees respectively for same months.

Other experiments by the same authorities show the same results, with some cases of a slight fall in temperature.

In the Wauwatosa plant described in Mr. Alvord's paper, temperatures were taken during the cold spell of December, 1901, with the following results: Temperature of air outside, about 4 degrees

Fah.; original sewage entering septic tank 48 degrees, in the controlling chamber between septic tank and sand beds 47 degrees, and entering creek at final outlet 44 degrees; a total loss of 4 degrees in extremely cold weather.

Therefore it seems to the writer beyond question, that no fear need be entertained of any serious trouble in operation of the septic purification plant due to cold weather in this climate. There is no doubt but that cold weather makes bacterial action more sluggish, but at the temperatures above shown the action will still continue at a rate sufficient for good purification.

## CXLIII.

# THE TRANSITION SPIRAL.

Wm. M. Torrance, M. W. S. E.

*Presented March 5, 1902.*

At the end of a railway curve there must be an appreciable length of track on which the super-elevation is increasing from zero at its tangent end to the super-elevation desired for the body of the circular curve.

It is quite evident that this piece of track should not be a piece from the end of the tangent, for if so, each successive portion of the train approaching the curve will acquire super-elevation where there is no centrifugal force and the effect on the riding quality of the train will be the same as it would be anywhere on the tangent, were one rail higher than the other. On the other hand, this piece of track should not be a piece from the end of the regular circular curve, for in that case each successive portion of the train entering the curve will find no super-elevation on the first part to take care of the centrifugal force, and the momentary effect will be the same on the riding quality of the train as if the track were unprovided with super-elevation.

Sometimes the super-elevation is acquired on a piece of track, one-half of which is on the tangent and one-half on the regular circular curve. This method is better than either of the two mentioned above, but is still open to the same objections.

Theoretically and practically the correct method of obtaining the super-elevation at the end of a railroad curve is to insert between the tangent and the circular curve a transition spiral in which the curvature increases from zero at its tangent end ($PS_1$ in Fig. 1) directly with the distance from that end to the curvature of the regular circular curve at its other end. ($PS_2$ in Fig. 1.)

The centrifugal force which renders super-elevation necessary, is directly proportional to the curvature at any point. If we introduce into the track on the spiral, super-elevation in exact proportion to the curvature in it, every condition for an easy riding track will be satisfied, for in that case the super-elevation is zero on the tangent, right up to the point where curvature begins. From that point to the point where the full super-elevation is acquired the curvatre is also being obtained, and in the same ratio.

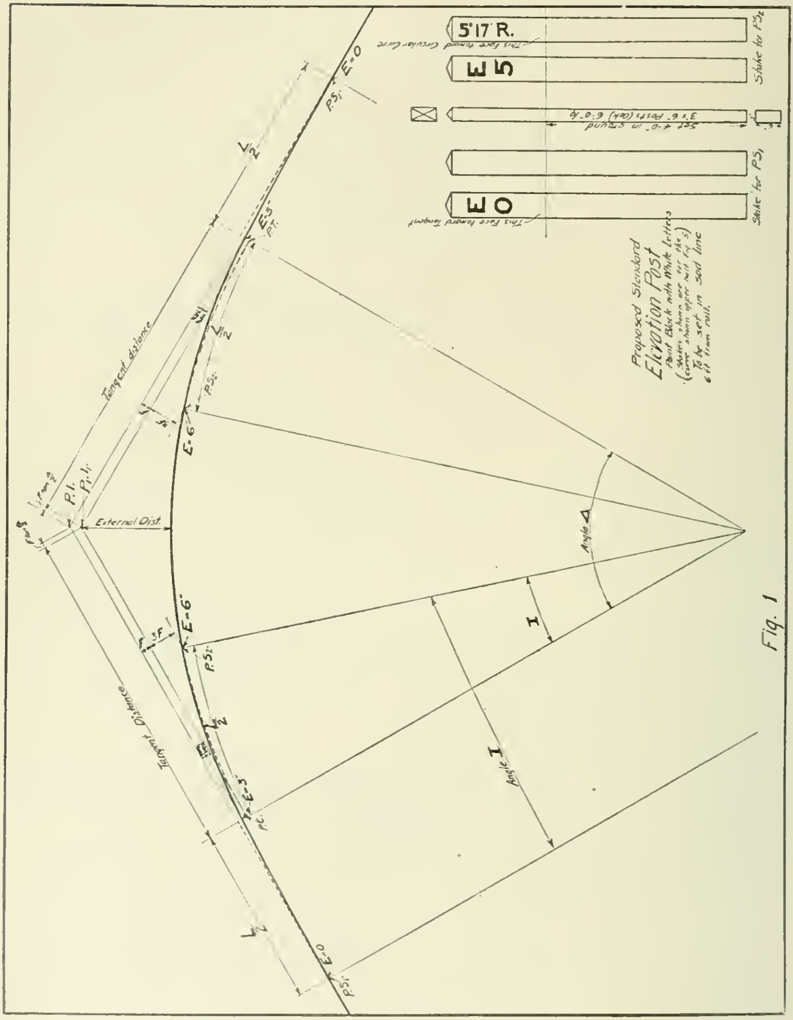


Fig. 1

It is often argued that it is hard to maintain a spiraled curve—both from a financial and engineering standpoint. It is doubtful if it is as difficult or expensive as if the curve were not spiraled. It is certain that a super-elevation runoff in ballast if made on the spiral, as it should be, will almost maintain itself, while if there is no spiral, and it is made on the tangent or on the circular curve, or partly on each, tangent and circular curve, it is certain to require constant attention on the part of trackmen. Trains passing through a curve will constantly change the surface of an unspiraled runoff by the vibratory forces introduced on account of not having the super-elevation and the curvature to match each other.

It is a fact that the trackmen, in order to save labor and expense in maintaining a good surface at the ends of curves, found out long ago the necessity of "easing off" the end of a curve. I think I am safe in saying that there are very few curves on any main line of railroads that have not thus been changed in line by the trackmen, if the engineer has not come to their aid by giving them spirals. This "easing off" of a curve as ordinarily practiced by the trackmen will often be found to have resulted in a line similar to that shown in Fig. 6 or upper half of Fig. 7, viz., the slight sharpening of the circular curve 200 or 300 feet back of the end of the curve in order to get a chance to throw the end of the curve "in" and gradually decrease the curvature to zero at a point some distance from the theoretical end of the curve on the tangent.

Why should not the railroad engineer come to the aid of the trackman and give him a line of stakes for this "easing off" that has been found necessary, a line that will allow the full accomplishment of what the trackman has attempted to do; that is, to get a change of curvature where there is required a change in super-elevation.

*It can be shown by calculus that the offsets from the line tangent to the transition spiral at its zero end, (line P S$_1$ to P I in Fig. 1,) to points on the spiral, are approximately proportional to the cubes of the distances to these points from the tangent or zero end.

It can also be shown by calculus that if the circular curve be produced back to a point (P. C.) where its tangent is parallel with the line tangent to the transition spiral at its zero end, this point P. C. will be opposite the middle point of the transition curve between its limits P S$_1$ and P S$_2$ (See Fig. 1.) and will also be at the same distance from this middle point as this middle point is from the tangent line through P S$_1$.

If we denote the whole offset distance between these parallel tangents by the letter "F" and the length of spiral from P S$_1$ to P S$_2$ by the letter "L", we may conveniently say that "F" and "L" mutually bisect each other at a point opposite the P. C. of the regular curve.

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*In all the Figures shown in this paper and in all the arithmetical work pertaining to them, the methods adopted are, to the writer's mind, practical ones, rather than theoretical. The assumptions made are such as will be found to be strictly correct for very flat curves and for short lengths of spiral, in which the chord is equal to the arc and the sine is proportional thereto. The ordinary range for railroad spirals will be for length of spiral less than 400 feet and for degree of curve less than 15 degrees, and the assumptions made will in all cases be so near correct for this range, as to make an inappreciable and negligible error.

Experience has shown that the transition spiral should be comparatively short,– 30 feet, or a rail length, for each ½ inch of super-elevation required on the body of the circular curve this being a good length and one easily remembered and applied by the trackmen.

The necessary data for staking out transition curves in the field are three, viz.: 1. The degree, "D", of the regular circular curve. 2. The length, "L", of spiral to be used. 3. The offset distance "F".

The offset distance, "F", can easily be computed from the first two, "D" and "L", it being simply equal to the one-third part of the perpendicular distance from the tangent through P. C. to the point P $S_2$ (See Fig. 1.). This perpendicular distance is equal to the product of the one-half length of the spiral ($\frac{L}{2}$) (which is also the distance along the circular curve from P. C. to P $S_2$) and the sine of the deflection angle for that much arc This deflection angle $= \frac{1}{2}$ (See Fig. 1.).

That this offset, "F", is equal to one-third of this product is readily seen from the fact that the perpendicular distance from the original tangent (P $S_1$ — P I) to a point on the spiral opposite P. C. is $\frac{F}{2}$ and to the spiral at P $S_2$ it is therefore $(2)^3 \times \frac{F}{2} = 4$ F. The tangent offset from the tangent through P. C. to P $S_2$ (the product just mentioned) is by construction equal to this quantity "4 F", less the distance, "F", between the parallel tangents; that is, it equals 3 F. Hence the proposition.

The table given at the end of this paper shows this offset "F" for all ranges of "D" and "L" liable to occur in ordinary practice, figured as outlined above, which, reduced to a formula, is

$$F = \frac{\frac{L}{2} \sin\left(\frac{\frac{L}{4}}{100} D\right)}{3} = \frac{L}{6} \sin\left(\frac{L}{400} D\right)$$

in which

L = Length of spiral in feet
D = Degree of curve
F = Spiral offset in feet

For example, if we were spiraling a 3° curve for 5″ super-elevation we would want a spiral 300 feet long, and our value for F would be $\frac{300}{6} \sin\left(\frac{300}{400} \times 3^\circ\ 00'\right) = 50 \sin 2^\circ\ 15' = 1.96$ ft.

We could also use a table of tangent offsets for 100 feet chords, such as is given in most field books, for obtaining "F". As it is approximately true that the tangent offset to a circular curve varies as the square of the distance from the tangent point (this is true for arcs up to 30°), our value for "F" using such a table will be

$$F = \left(\frac{(\frac{L}{2})^2}{(100)^2} \times \text{tangent offset for } 100'\right) \div 3$$

$$= \frac{(L)^2}{120000} \times \text{tangent offset for } 100'$$

Thus, in the case of the 3° curve and 300 feet spiral given above

$$F = \frac{9}{12} \times 2.61 \text{ (from table)} = 1.96 \text{ ft.}$$

Another formula, an arbitrary one, but one conveniently remembered, and thus usable if no tables of sines or tangent offsets are at hand, and one nearly as accurate as the two just given is

$$F = .0000072\ L^2 D \text{ or } F = \left(\tfrac{L}{100}\right)^2 \times .072\ D$$

Thus in the case of the 3° curve and 300 feet spiral given above

$$F = \left(\tfrac{3}{1}\right)^2 \times .072 \times 3 = 1.94 \text{ ft.}$$

After having determined the degree for the circular curve, with the length for the transition spiral, and, from them the spiral offset "F", the method of procedure for staking out the circular curve with spirals is as follows.

Run the tangents to the P. I., as for an ordinary curve.

Set a stake at $P_1I_1$, the intersection of the offset tangents. (See Fig. 1.)

Locate P. C. and P. T. from the point $P_1$ $I_1$ and the angle $\Delta$ as for an ordinary curve.

From points opposite P. C. and P. T. on the original tangents, measure still further from P. I. the distance $\frac{L}{2}$ and thus locate the points of spiral P $S_1$, (the tangent ends of the transition curves, where curvature and super-elevation are both to be zero.)

Run in the regular curve between P. C. and P. T. as for an ordinary curve, except that no stakes need be set for less distances than $\frac{L}{2}$ from either point. At the distance $\frac{L}{2}$ set the points of spiral P $S^2$. The procedure may now take either of two courses. The points P S, P. C. or P. T., and P $S_2$ are in position at each end of the curve, and the spirals may be staked out by offsets or by deflections.

For ordinary cases the method of offsets is preferable, using offsets from the original tangent for the first half and from the curve for the second half. To save computation it is much easier to disregard regular stationing between the ends of the spiral and divide the distance (="L") into some convenient even number of parts so as to obtain stakes as close to each other as desired. (See Fig. 2.)

While setting stakes on the body of the curve, temporary stakes or tacks can be set between P. C. and P $S_2$ and the offsets as shown in Fig. 2 can then be measured out to the proper position for stake points on the spiral, and while the instrument is on the tangent through P $S_1$ temporary points in like manner can be set on the tangent between P $S_1$ and a point opposite P. C. and the offsets measured in for the stake points of the spiral.

The offset distance from the tangent to the spiral at any given

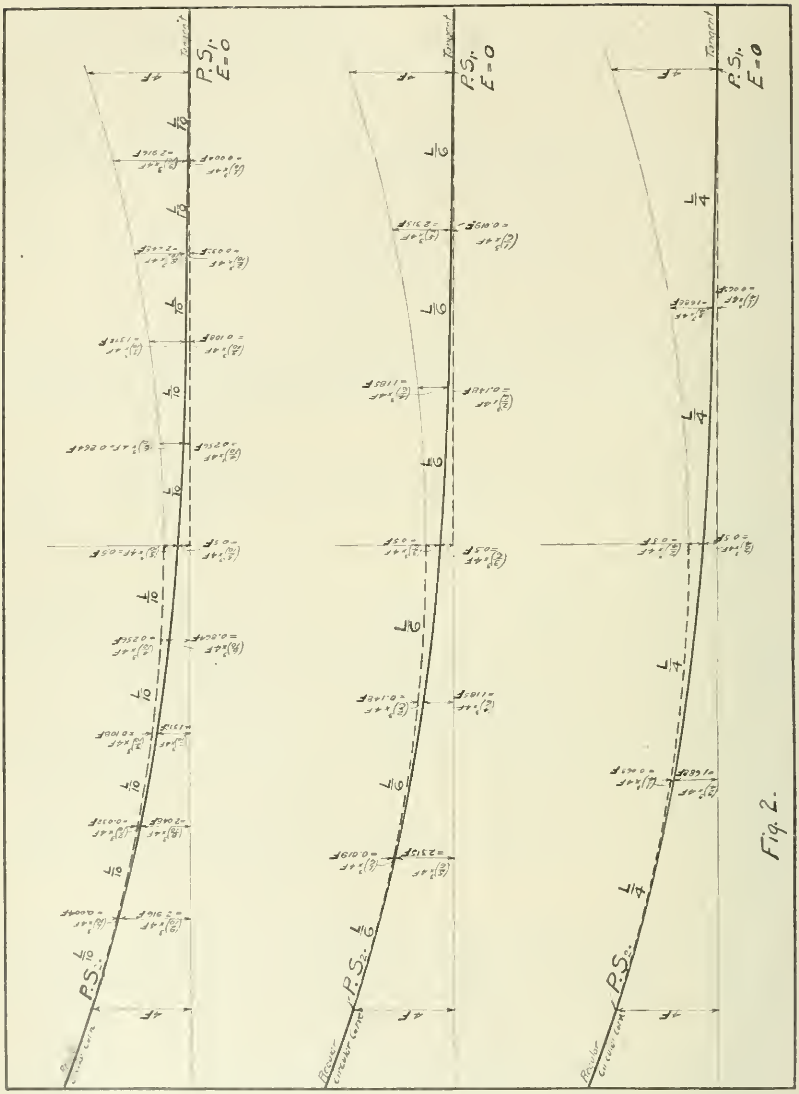

Fig. 2.

distance from P S$_1$ is always equal to the offset distance from the curve to a point on the spiral at that same distance from P S$_2$.

To run in the transition curve by deflections with the instrument at P. S$_1$ and vernier at zero on P. I., the deflections are proportional to the squares of distances from P S$_1$, the deflection to P S$_2$ being the one-third part of the angle I which, as shown in Fig. 3, is the central angle subtended by the arc $\frac{L}{2}$ of the regular circular curve.

Thus the deflection

to the $\frac{1}{4}$ point will be $\frac{1}{3} \times (\frac{1}{4})^2 = \frac{1}{48}$ I
to the middle point will be $\frac{1}{3} \times (\frac{1}{2})^2 = \frac{1}{12}$ I
to the $\frac{3}{4}$ point will be $\frac{1}{3} \times (\frac{3}{4})^2 = \frac{3}{16}$ I

To run in the transition curve by deflections with the instrument at P $S_2$ and the vernier at zero on the line tangent to the curve at

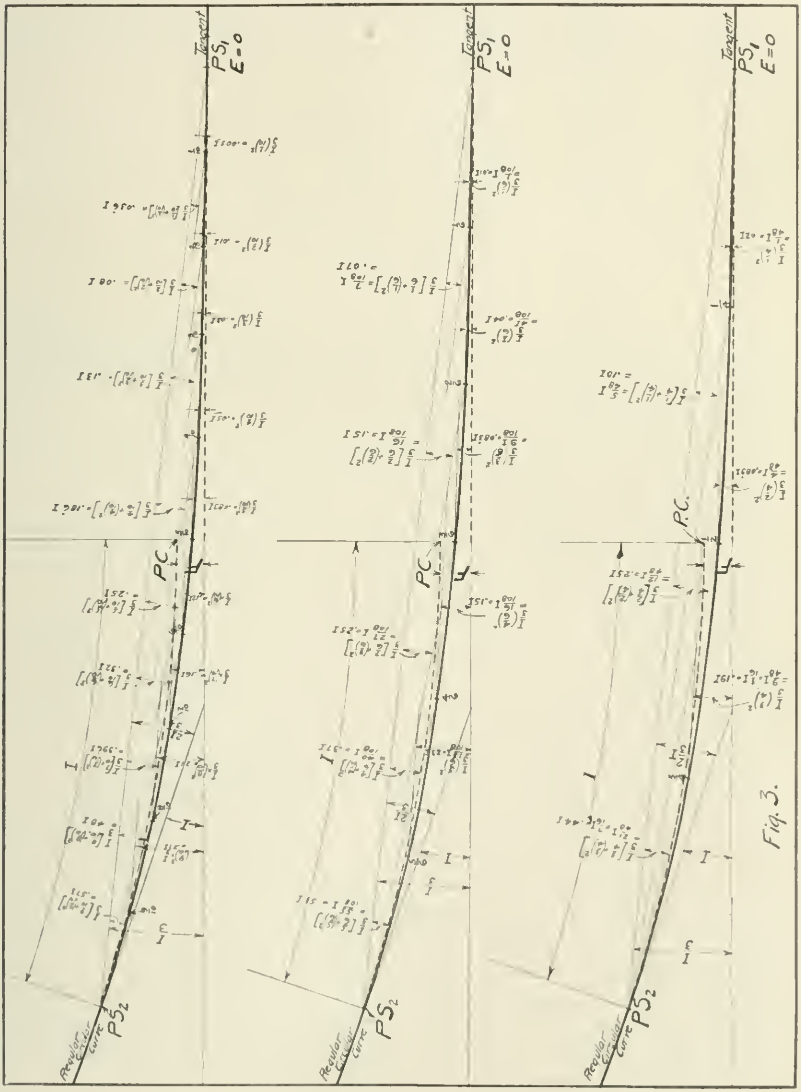

Fig. 3.

that point (also tangent to the circular curve), first turn the deflection angle for the point P S which is $\frac{2}{3}$I and verify the position of that point. Then with the instrument still at P $S_2$ and vernier zero on P $S_1$ the deflection angles to points between are proportional to the quantity $n+n^2$ (in which n is the ratio of the distance from P $S_1$ to the total length P $S_1$—P $S_2$ = L) and are equal to $\frac{2I}{3} \times \left(\frac{n+n^2}{2}\right)$, $\frac{n+n^2}{2}$ being unity for the point P $S_2$.

Thus the deflection angle between P $S_1$ and the quarter point (instrument at P $S_2$) is

$$\frac{2I}{3} \times \frac{(\frac{1}{4}+\frac{1}{16})}{2} = \frac{5}{48} I ;$$

between P $S_1$ and the middle point it is

$$\frac{2I}{3} \times \frac{(\frac{1}{2}+\frac{1}{4})}{2} = \frac{1}{4} I$$

and between P $S_1$ and the three-quarter point it is

$$\frac{2I}{3} \times \frac{(\frac{3}{4}+\frac{9}{16})}{2} = \frac{7}{16} I$$

In new railroad work it would be a good plan to determine beforehand the length of spiral desired for each condition liable to occur on the work—some such rule as that curves up to 6° should have super-elevation 1″ per degree, and curves sharper than 6° should have 6″ super-elevation, and that the spiral should be 30 feet per each ½″ super-elevation so determined.

In location, the transition spirals need not be run in, but the P C and P T can be simply offset in from the tangents the proper distance "F" leaving hubs at both ends of the offsets, and then run in the regular curve on the regular stationing between them.

In construction the engineer will have the two offset hubs at each end of the curve as left by the location engineer, and from them and the location notes he will put in the spiral center line before setting the cross-section stakes for grading. The engineering work of getting the line graded to the line of a spiraled curve should be very little more than to the line of an unspiraled curve.

When giving stakes for track centers after the grading is done and the track is about to be laid, prominent posts should be set eight or ten feet to the side of the track opposite the P $S_1$ and P $S_2$ at each end of the curve, plainly painted with E–0 and E–6 (or E–4, or whatever the number of inches super-elevation are to be given the body of the curve), the E–0 posts being set opposite the P $S_1$ points, and the E–6 posts opposite the P $S_2$ points. (See Fig. 1.) Then the track inspector's duty is to see that the track is surfaced level on the tangents up to points opposite the E–0 posts, and that from there to the E–6 posts the super-elevation of 6 inches (in the case mentioned) is acquired proportionately to the distance from the E 0 posts, and that between the E 6 posts the super-elevation is 6 inches.

The cost of construction of a new railroad should be the same whether its curves be spiraled or not.

In maintenance work the problem of getting the curves spiraled is more difficult. It will nearly always be found that the curves were originally, and so are now practically, of integral degree, but to spiral them and not throw the track off the roadbed, the engineer may find it necessary to sharpen the curve a few minutes, thus leaving his curves not of integral degree.

Fig. 4 shows a 3° curve with 11° central angle. A curve like this, if in the open country, should have 4″ super-elevation, and spirals for it should be 240 feet long.

The lower half of the figure shows in light dashed line the center line of the track as found (a regular 3° curve without spirals), and in a full line the center line as spiraled with the condition of maintaining the integral degree of the curve.

The upper half of the figure shows the method of spiraling this curve so as not to change to any extent the length of the track and to reduce to a minimum the

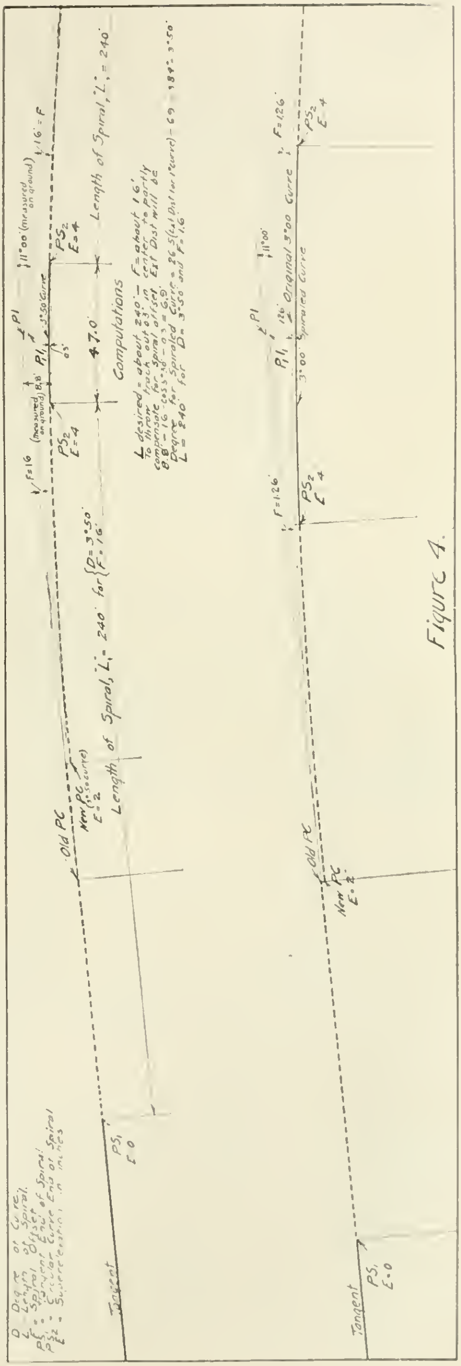

Figure 4.

transverse movement or throw necessary to obtain a spiraled curve, thus leaving the track practically entirely on its old roadbed.

In the case of such a short curve, the second method sharpens the curve in a considerable proportion, and it may be that good judgment would be to adopt the first method, which does not increase the degree of curvature.

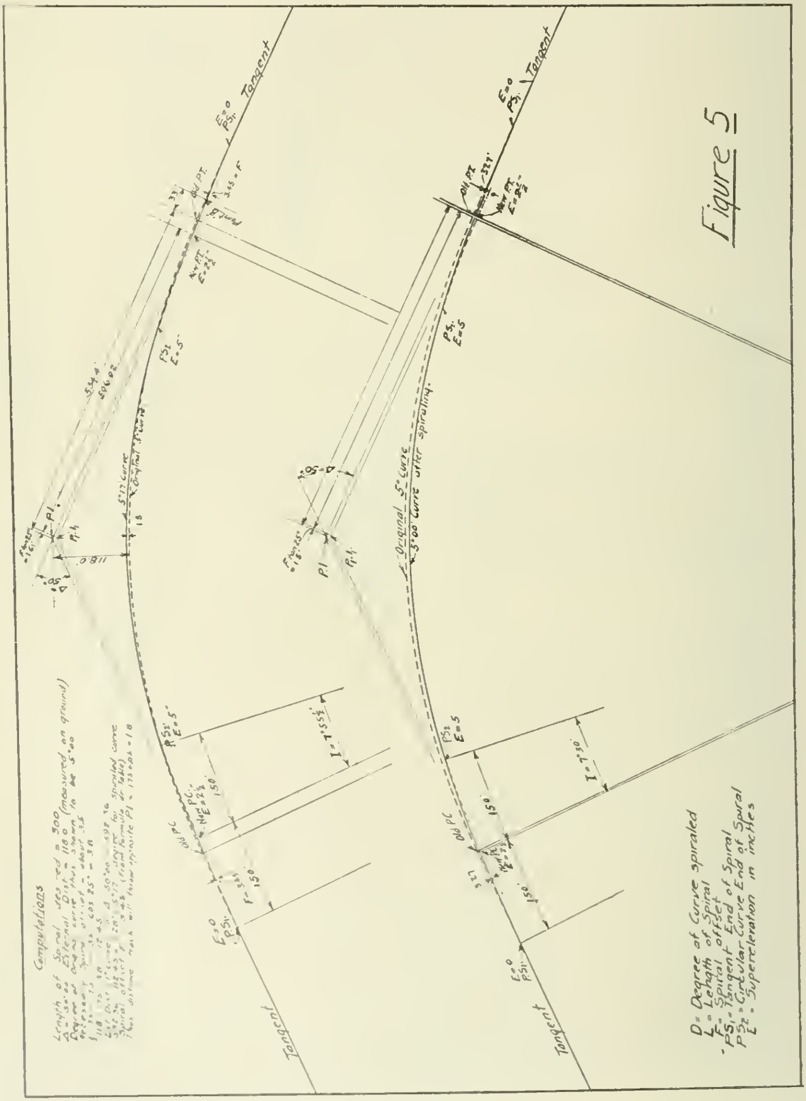
Tangent
E=0
PS1
Old PT
New PT
PS2
E=5
Original 5° curve
5°00 curve after spiraling
P.I.
Old PC
New PC
150'
I=7°30'
Computations
D= Degree of Curve spiraled
L= Length of Spiral
F= Spiral offset
PS1= Tangent End of Spiral
PS2= Circular Curve End of Spiral
E= Superelevation in inches

Figure 5

This method throws the track in more than one foot for the entire length of the curve, however, and the finished length of track is shorter than that found, thus necessitating the cutting out of pieces of rail, which extra labor the second method avoids.

In the case shown in Fig. 5, that of a 5° curve of central angle 50°, it would be much the better judgment to adopt the method of spiraling shown in the upper half of the figure, as the spiral offset "F" is so large that if the method shown in lower half of the figure were adopted, nearly half the length of the ties would be on new roadbed, while the remainder would remain on old, hard packed bottom, with the result that good surface for the track would be hard to maintain for a considerable time, and furthermore the method shown in the upper half of the figure does not contemplate sharpening the curve in a very appreciable proportion.

As a general proposition it will be true that the track as found will not be exactly on its true circular curve, and unless it is so found it would be useless to try to use any formula, such as given in theoretical works on the transition spiral, to make sure that the rails will not have to be cut.

A good method to be adopted to practically insure this result is as shown in the upper half of Fig. 5. The P. I. is located by running to it, on the ground if possible, or by calculation if inaccessible, and the central angle and the existing external distance (50° and 118′ in this case) are then measured or calculated. These data show the curve to have been originally a 5° curve, and that the line still conforms closely to that curve. It is noted from the table for "F" that this offset will be about 3.5 feet for a spiral such as is wanted (300 feet long.)

To change the length as little as possible it is probable that it will be necessary to throw the curve out at its center by a quantity $\frac{F}{2} = 1.75$, so we find that the degree for our curve will be $5^\circ.28 = 5^\circ - 17'$, being the degree for a curve of 50° central angle and external distance $= 118 - (\frac{F}{2} + \frac{F}{\cos 25^\circ}) = 112.45$ feet. The value for F with $D = 5^\circ.28$ and $L = 300$ feet is found to be 3.45 feet, and the $5^\circ - 17'$ curve and 300 feet spirals are then staked out, as previously discussed.

When the central angle is large, it is difficult to adopt the method just discussed, on account of the difficult field work or calculation necessary to locate the P. I. and determine the point of intersection. It will be comparatively easy, however, to re-run the original center line, originally a curve of integral degree and often monumented. To spiral such a curve one method would be as shown in Fig. 6. This method contemplates the re-running of the original curve, setting final center stakes on all except a few stations at each end where the curve is compounded to one somewhat sharper, and thus obtaining room for a spiral offset "F," for spirals.

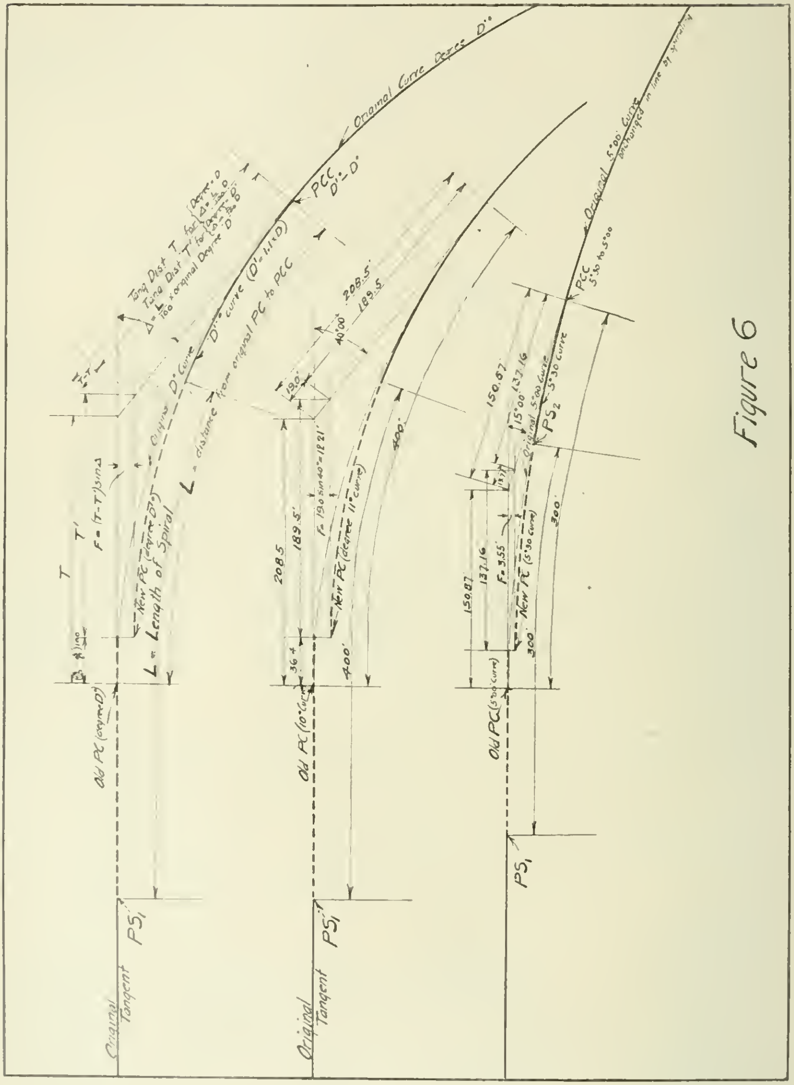

Figure 6

In the cases illustrated in the figure the curve is compounded to curves of 10% greater curvature. It will always be found true that with this increase in curvature, the offset "F" obtained will be

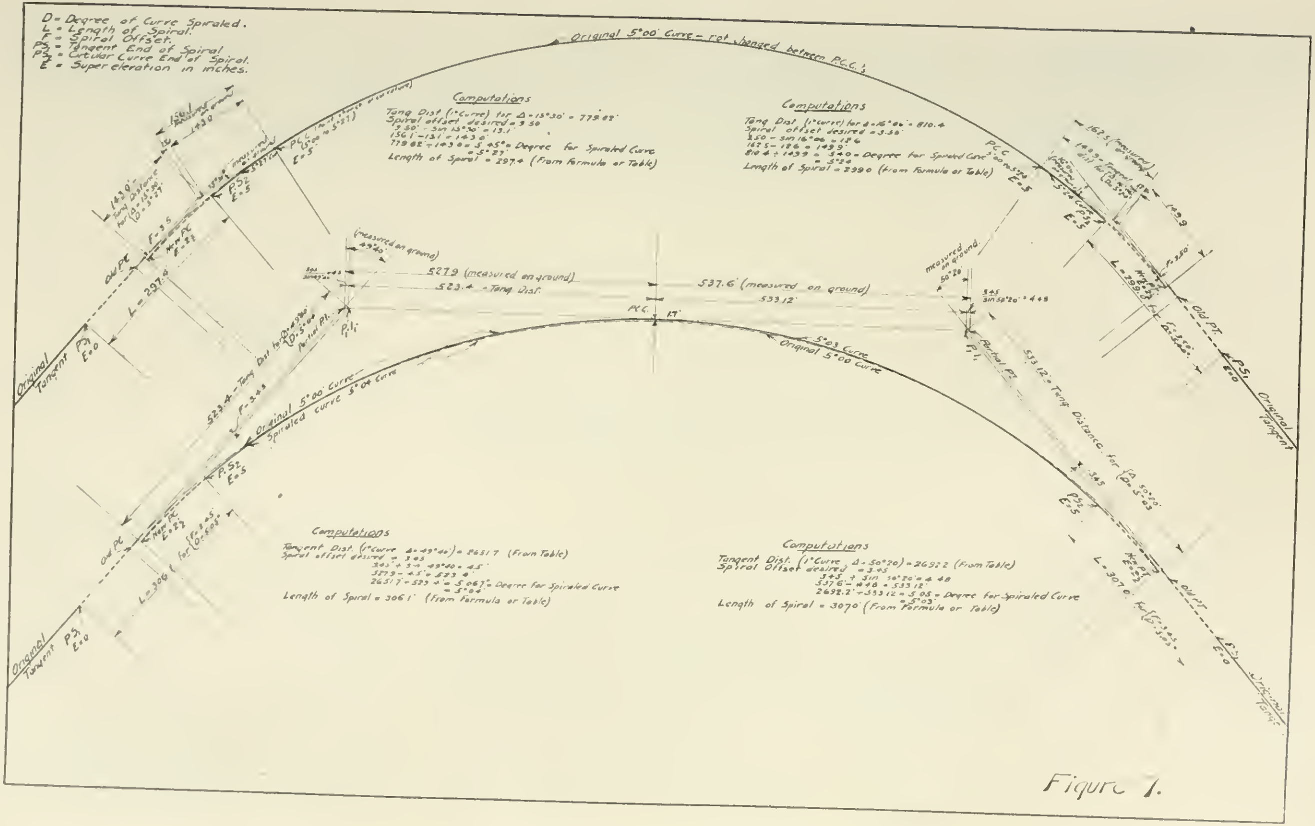
D = Degree of Curve Spiraled.
L = Length of Spiral.
F = Spiral Offset.
PS₁ = Tangent End of Spiral
PS₂ = Circular Curve End of Spiral.
E = Superelevation in inches.
Original 5°00' Curve – not changed between P.C.C.'s
Computations
Tang Dist (1° Curve) for Δ = 15°30' = 779.82'
Spiral offset desired = 3.50
3.50' ÷ sin 15°30' = 13.1'
156.1' – 13.1' = 143.0'
779.82' ÷ 143.0 = 5.45° = Degree for Spiraled Curve
= 5°27'
Length of Spiral = 297.4 (From Formula or Table)
Computations
Tang Dist (1° curve) for Δ = 16°06' = 810.4
Spiral offset desired = 3.50'
3.50 ÷ sin 16°06' = 12.6
162.5 – 12.6 = 149.9'
810.4 ÷ 149.9 = 5.40 = Degree for Spiraled Curve
= 5°24
Length of Spiral = 299.0 (from Formula or Table)
P.C.C.
E = 5
Original Tangent
PS₁
E = 0
Old PC
New PC
E = 2.5
F = 3.5
L = 297.4
143.0' Tang Distance for Δ = 15°30' D = 5°27'
156.1 (measured on ground)
PS₂
E = 5
P.C.C.
(measured on ground) 49°40'
527.9 (measured on ground)
523.4 = Tang. Dist.
P.I.
Partial P.I.
523.4 – Tang Dist for Δ = 49°40' D = 5°04'
F = 3.45
Original 5°00' Curve
Spiraled curve 5°04' Curve
P.C.C.
1.7'
537.6' (measured on ground)
533.12'
measured on ground 50°20'
3.45 / sin 50°20' = 4.48
P.I.
Partial P.I.
5°03 Curve
Original 5°00 Curve
533.12' = Tang. Distance for Δ = 50°20' D = 5°03
3.45
PS₂
E = 5
5°24 Curve
162.5 (measured on ground)
149.9 = Tangent dist for Δ = 16°06' D = 5°24
149.9
F = 3.50
New P.T.
E = 2.5
L = 299.0 for F = 3.50 D = 5°24
Old P.T.
PS₁
E = 0
Original Tangent
New PC
E = 2.5
Old PC
L = 306.1 for F = 3.45 D = 5°04
PS₁
E = 0
Original Tangent
Computations
Tangent Dist. (1° Curve Δ = 49°40') = 2651.7 (From Table)
Spiral offset desired = 3.45
3.45' ÷ sin 49°40 = 4.5'
527.9 – 4.5' = 523.4'
2651.7 ÷ 523.4' = 5.067° = Degree for Spiraled Curve
= 5°04'
Length of Spiral = 306.1' (From Formula or Table)
Computations
Tangent Dist. (1° Curve Δ = 50°20) = 2692.2 (From Table)
Spiral Offset desired = 3.45
3.45 ÷ sin 50°20' = 4.48
537.6' – 4.48 = 533.12'
2692.2' ÷ 533.12 = 5.05 = Degree for Spiraled Curve
= 5°03'
Length of Spiral = 307.0' (From Formula or Table)
New P.T.
E = 2.5
L = 307.0 for F = 3.45 D = 5°03
Old P.T.
PS₁
E = 0
Original Tangent

Figure 1.

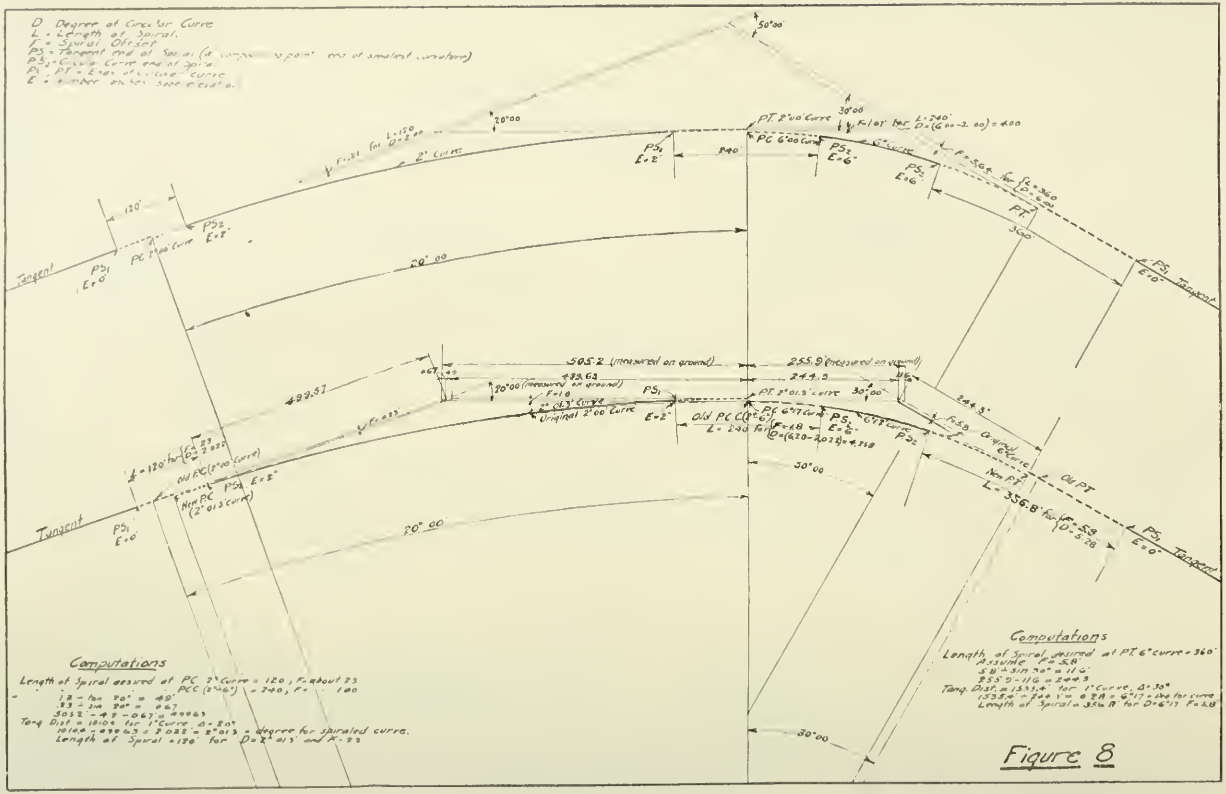
D Degree of Circular Curve
L = Length of Spiral.
F = Spiral Offset
PS₁ = Tangent end of Spiral (or [illegible] point end of smallest curvature)
PS₂ = Circular Curve end of Spiral.
PC, PT = Ends of circular curve
E = [illegible] inches [illegible] elevation.
50°00'
30°00
20°00
PT. 2°00' Curve
PC 6°00' Curve
F=1.01' for L=240' D=(6°00-2°00)=4°00
6° Curve
F=5.64 for L=360 D=6°00
PS₁ E=2"
240'
PS₂ E=6"
PS₂ E=6"
PT.
360'
PS₁ E=0" Tangent
F=.21 for L=120 D=2°00
2° Curve
120'
PS₂ E=2"
PC 2°00' Curve
Tangent
PS₁ E=0"
20° 00
505.2 (measured on ground)
255.9' (measured on ground)
493.63
244.3
.067
.49
1.16
20°00 (measured on ground)
F=1.0
2° 01.3' Curve
Original 2°00' Curve
PS₁
E=2"
PT. 2° 01.3' curve
30°00
PC 6°17' Curve
Old PC C(2°-6°)
L=240 for F=1.8 D=(6.20-2.022)=4.258
PS₂ E=6"
6°17' Curve
P.S₂
244.3'
F=5.8
Original 6° Curve
Old PT
New P.T.
L=356.8' for F=5.9 D=5.28
PS₁ E=0" Tangent
30°00
499.57
F=.83
L=120' for F=.83 D=2.022
Old P.C (2°00' curve)
New P.C (2° 01.3' curve)
PS₂ E=2"
Tangent
PS₁ E=0"
20° 00
30°00
Computations
Length of Spiral desired at PC 2° Curve = 120, F = about .83
" " " " PCC (2°-6°) = 240, F = " 1.00
.12 ÷ tan 20° = .49'
.23 ÷ sin 20° = .067
505.2' - .49 - .067' = 499.63
Tang Dist = 1010.4 for 1° Curve Δ = 20°
1010.4 ÷ 499.63 = 2.022 = 2° 01.3 = degree for spiraled curve.
Length of Spiral = 120' for D = 2° 01.3' and F = .83
Computations
Length of Spiral desired at PT. 6° curve = 360'
Assume F = 5.8'
5.8' ÷ sin 30° = 11.6'
255.9' - 11.6 = 244.3
Tang. Dist. = 1535.4' for 1° Curve, Δ = 30°
1535.4' ÷ 244.3' = 6.28 = 6°17 = Deg. for curve
Length of Spiral = 356.8' for D = 6°17 F = 5.8

Figure 8

approximately correct for a spiral length equal to the length taken away from the original curve.

This makes an easy way of spiraling curves and could readily be made use of in construction work if it should be decided to use spiraled curves after grading had been completed on the line of unspiraled ones.

A modification of this method of spiraling long curves is shown in the upper half of Fig. 7, which, in most cases, will be found simpler than to re-run the whole original curve as a preliminary. In this method the middle portion of the curve only is re-run, finding by experiment a line that will throw the track but little, and using the original integral degree or varying from it slightly as desired. Tangents are run out from the curve so re-run at points near the ends (3 or 4 stations back) to intersect the tangents of the whole curve, and then, as shown in the figure, curves are calculated for these end portions that will allow spiraling and not leave any pieces of tangent at the compounding points.

These last methods discussed are somewhat objectionable in that there is introduced a short portion of somewhat sharper curve, but the advantages will more than compensate in many cases, as labor in changing line is saved and the percentage of increase in curvature is too slight to materially affect the riding quality of the train.

A modification is shown in the lower half of Fig. 7 that does away with this objection. In this method a tangent is taken to the existing track center line at a point near the center, and a parallel line, distant 1.7 feet (approximately the value which will be obtained for $\frac{F}{2}$) outside this tangent line, is run to intersect the tangents of the curve. The calculations for determining the proper spirals are shown on the figure. It may be, however, that the labor of obtaining these spirals in track work will be greater than in the method shown in upper half of the figure.

The proper length of spiral to insert between the points of a compound curve depends on the amount of super-elevation demanded by the traffic for these parts. If the same super-elevation is maintained around the whole curve, no spiral is needed, for by hypothesis a spiral is inserted to properly obtain a change in super-elevation. Fig. 8 (upper part) shows the proper spiraling of a 2° — 6° compound curve (assuming 1″ super-elevation per degree, and 30 feet for each ½″ super-elevation, in length.) It is assumed in the figure, and is capable of proof, that the spiral offset between the tangents shown at the compounding point is the same as for a curve of degree equal to the difference of degree between the parts of the compound curve, e. g., for a 4° curve in this case.

This case shown is one such as might be chosen for an original location. In an actual case of adding spirals to an unspiraled curve on maintenance work, a thorough survey of the curve should first be made, and from the notes of such a survey a satisfactory arrangement of the center line to enable spiraling is not hard to find.

In Fig. 8, lower part of figure, it is supposed that a survey of an existing center line has been made showing it to be a 2° — 6° compound curve, similar to the curve shown in the upper half of the figure, but unspiraled. The figure shows a possible method of spiraling this curve for a 2″ super-elevation on the 2° part and 6″ super-elevation on the 6° part, the spirals being approximately of length, 30 feet per ½″ super-elevation acquired thereon.

In Fig. 9 is shown the spiraling of a reversed curve. This is an exaggerated case in which the two branches come to an exact reversing point. It is most necessary in such a case to have spiraling, for we have not only to reduce the superelevation from the one arm to zero, but must increase from zero to the superelavation of the other arm, all in a very limited space. In case of such a curve, unspiraled, all of the "run off" would be in the curve in either case.

In order to get a chance to spiral the parts of this curve, a new tangent line is chosen at the reversing point, such as to throw the track "in" somewhat on both branches (this new tangent line being chord lines of the old branches of the curve) and the spirals are obtained on curves somewhat sharper than the original. In the case as shown, the calculations given on the figure were made such as to give a spiral length of 30 feet for each ½ inch of super-elevation desired, and the track shown as thrown "out" for a considerable portion of the length of both arms of the curve so as to probably nearly equalize the throw "in" near the reversing point.

This same method is of course applicable in case the curves are separated by a tangent too short to allow spiraling instead of coming to an exact reversing point, as in the case illustrated.

When a bridge is located near the end of a curve it is of importance that the curve should be spiraled. Very often bridges are located just off the curve, with the end of the bridge so near that a train passing from the curve is still affected by the lateral forces induced by passing from the unspiraled curve, with the result that the bridge is "hit hard" by the train, causing stresses in its members that could be avoided by adding spirals to the curve. In the case of such an unspiraled curve, the bridgemen and trackmen are prone to keep the super-elevation zero on the bridge and make the runoff shorter than they would normally.

For example, in the case of Fig. 5, suppose the end of the bridge were at the point marked "B" on that figure, 33 feet from the original P. T. of the curve. The engineer, in such a case, would

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# TABLE OF SPIRAL OFFSETS "F."

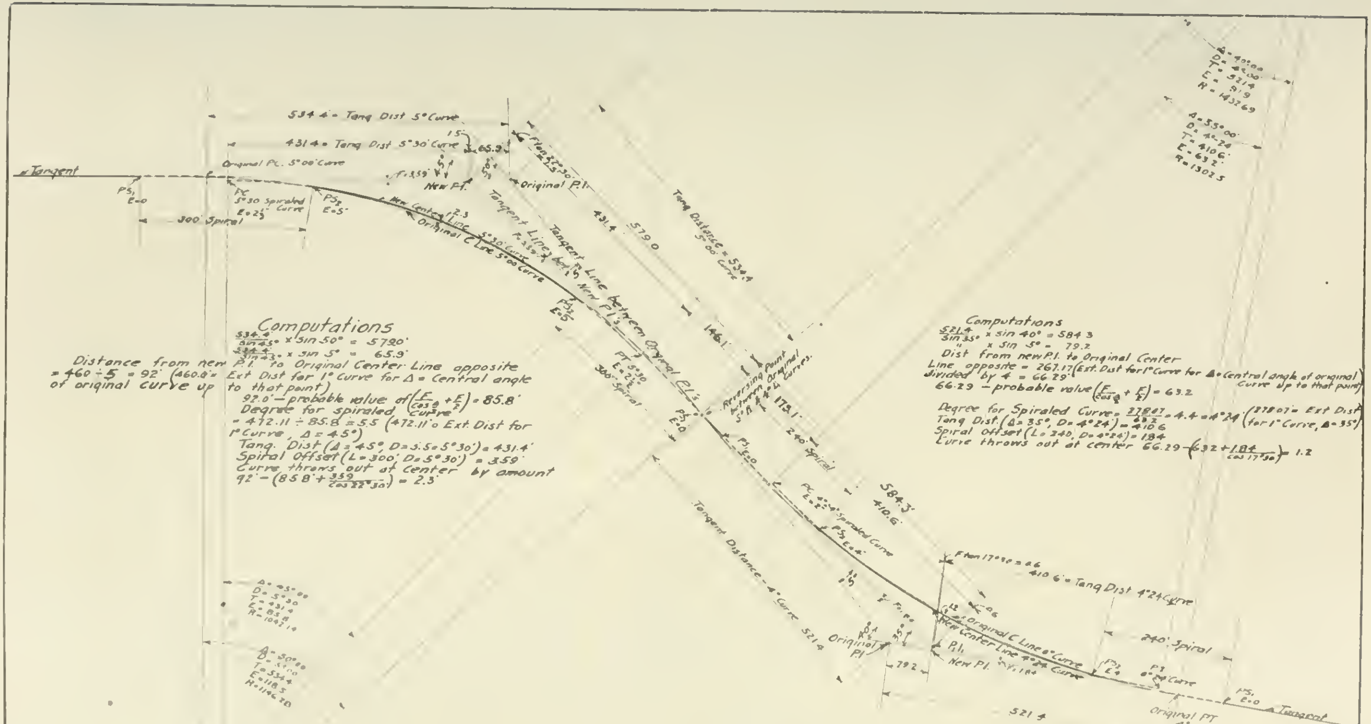
LENGTH OF SPIRAL.

Degree of Spiraled Curve.

| | 80 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 | 260 | 280 | 300 | 320 | 340 | 360 | 380 | 400 | 420 | 440 | 460 | 480 | 500 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1°00 | 0.05 | 0.07 | 0.10 | 0.14 | 0.18 | 0.23 | 0.29 | 0.35 | 0.42 | 0.49 | 0.57 | 0.65 | 0.74 | | | | | | | | | | 1°00 |
| 10 | .05 | .08 | .12 | .16 | .21 | .27 | .34 | 41 | 0.49 | 0.57 | 67 | 76 | 86 | | | | | | | | | | 10 |
| 20 | .06 | .10 | .14 | .19 | .24 | .31 | .39 | 47 | 56 | 65 | 76 | 87 | 0.99 | | | | | | | | | | 20 |
| 30 | .07 | .11 | .16 | .21 | .27 | .35 | 44 | .53 | 63 | 73 | 86 | 97 | 1.11 | | | | | | | | | | 30 |
| 40 | .08 | .12 | .18 | .23 | .31 | 39 | 48 | 58 | 70 | 82 | 95 | 1.08 | 24 | | | | | | | | | | 40 |
| 50 | .09 | .13 | .19 | .26 | .34 | .43 | .53 | 64 | 77 | 90 | 1.05 | 19 | 36 | | | | | | | | | | 50 |
| 2°00 | 0.09 | 0.14 | 0.21 | 0.28 | 0.37 | 0.47 | 0.58 | 0.70 | 0.84 | 0.98 | 1.14 | 1.30 | 1.49 | 1.68 | 1.88 | 2.10 | 2.33 | 2.57 | | | | | 2°00 |
| 10 | .10 | .15 | .23 | .30 | 40 | .51 | .63 | 76 | 91 | 1.06 | 24 | 41 | 61 | 82 | 2.04 | 27 | 52 | 78 | | | | | 10 |
| 20 | .11 | .17 | .24 | .33 | 43 | .55 | 68 | 82 | 0.98 | 14 | 33 | 52 | 74 | 1.96 | 20 | 45 | 71 | 2.99 | | | | | 20 |
| 30 | .12 | .18 | 26 | .35 | 46 | .59 | .73 | 88 | 1.05 | 22 | 43 | 63 | 86 | 2.10 | 36 | 62 | 2.91 | 3.21 | | | | | 30 |
| 40 | .12 | .19 | .28 | .37 | 49 | .62 | .77 | 93 | 12 | 31 | 52 | 74 | 1.98 | 24 | 51 | 80 | 3.10 | 42 | | | | | 40 |
| 50 | .13 | .21 | .30 | .40 | .52 | .66 | .82 | 0.99 | 19 | 39 | 62 | 85 | 2.10 | 38 | 67 | 2.97 | 29 | 63 | | | | | 50 |
| 3°00 | 0.14 | 0.22 | 0.31 | 0.42 | 0.55 | 0.70 | 0.87 | 1.05 | 1.26 | 1.47 | 1.71 | 1.96 | 2.23 | 2.52 | 2.83 | 3.15 | 3.49 | 3.85 | 4.22 | 4.62 | 5.02 | 5.45 | 3°00 |
| 10 | .15 | 23 | 33 | 44 | .58 | .74 | 92 | 11 | 33 | 55 | 81 | 2.07 | 35 | 66 | 2.98 | 32 | 68 | 4.06 | 46 | 4.88 | 30 | .76 | 10 |
| 20 | .16 | .24 | .35 | 47 | .61 | .78 | 0.97 | 17 | 40 | 63 | 1.90 | 18 | 48 | 80 | 3.14 | 50 | 3.87 | 27 | 69 | 5.14 | 58 | 6.06 | 20 |
| 30 | .16 | .25 | .37 | 49 | .64 | .82 | 1.02 | 23 | 47 | 71 | 2.00 | 29 | 60 | 2.94 | 30 | 67 | 4.07 | 49 | 4.92 | 39 | 5.86 | .36 | 30 |
| 40 | .17 | .26 | .38 | .52 | .68 | .86 | .06 | 28 | 53 | 80 | 09 | 40 | 73 | 3.08 | 45 | 3.85 | 26 | 70 | 5.16 | 65 | 6.14 | .66 | 40 |
| 50 | .18 | .28 | .40 | .55 | .71 | .90 | .11 | 34 | 60 | 88 | 19 | 51 | 85 | 22 | 61 | 4.02 | 45 | 4.91 | 29 | 5.90 | 42 | 6.97 | 50 |
| 4°00 | 0.19 | 0.29 | 0.42 | 0.57 | 0.74 | 0.94 | 1.16 | 1.40 | 1.67 | 1.96 | 2.28 | 2.62 | 2.98 | 3.36 | 3.77 | 4.20 | 4.65 | 5.13 | 5.63 | 6.15 | 6.70 | 7.27 | 4°00 |
| 10 | .19 | .30 | 44 | .59 | .77 | 0.98 | .21 | 46 | 74 | 2.05 | 38 | 73 | 3.10 | 50 | 3.92 | 37 | 4.84 | 34 | 5.86 | 41 | 6.98 | 57 | 10 |
| 20 | .20 | .31 | .45 | .62 | .80 | 1.02 | .26 | 52 | 81 | 13 | 47 | 83 | 23 | 64 | 4.08 | 55 | 5.03 | 55 | 6.10 | 66 | 7.25 | 7.87 | 20 |
| 30 | .21 | .32 | .47 | .64 | .83 | .06 | .31 | 58 | 88 | 21 | 57 | 2.94 | 35 | 78 | 24 | 72 | 23 | 77 | 33 | 6.92 | .53 | 8.17 | 30 |
| 40 | .22 | .33 | .49 | .66 | .87 | .10 | .35 | 64 | 1.95 | 30 | .66 | 3.05 | 47 | 3.92 | 39 | 4.90 | 42 | 5.98 | 56 | 7.17 | 7.81 | 47 | 40 |
| 50 | .23 | .35 | .51 | .69 | .90 | .14 | .40 | 70 | 2.02 | 38 | .76 | 16 | 60 | 4.06 | 55 | 5.07 | 61 | 19 | 6.80 | 43 | 8.08 | 8.77 | 50 |
| 5°00 | 0.23 | 0.36 | 0.52 | 0.71 | 0.93 | 1.18 | 1.45 | 1.76 | 2.09 | 2.46 | 2.85 | 3.27 | 3.72 | 4.20 | 4.71 | 5.25 | 5.81 | 6.41 | 7.03 | 7.68 | 8.36 | 9.07 | 5°00 |
| 10 | .24 | 37 | .54 | .73 | .96 | .22 | .50 | 82 | 16 | 54 | 2.95 | 38 | 84 | 34 | 4.86 | 42 | 6.00 | 62 | 26 | 7.94 | .64 | 37 | 10 |
| 20 | .25 | .39 | .56 | .76 | 0.99 | .26 | .55 | 88 | 23 | 62 | 3.04 | 48 | 3.97 | 48 | 5.02 | 60 | 19 | 6.83 | 50 | 8.19 | 8.91 | .67 | 20 |
| 30 | .25 | .40 | .58 | .78 | 1.02 | .30 | .60 | 94 | 30 | 70 | 14 | 59 | 4.09 | 62 | 18 | 77 | 39 | 7.05 | 73 | 44 | 9.19 | 9.97 | 30 |
| 40 | .26 | .41 | .59 | .80 | .06 | .33 | .64 | 1.99 | 37 | 79 | 23 | 70 | 21 | 76 | 33 | 5.95 | 58 | 26 | 7.96 | 70 | 47 | 10.3 | 40 |
| 50 | .27 | .43 | .61 | .83 | .09 | .37 | .69 | 2.05 | 44 | 87 | 33 | 81 | 34 | 4.90 | 49 | 6.12 | 77 | 47 | 8.20 | 8.95 | 9.73 | 6 | 50 |
| 6°00 | 0.28 | 0.44 | 0.63 | 0.86 | 1.12 | 1.41 | 1.74 | 2.11 | 2.51 | 2.95 | 3.42 | 3.92 | 4.46 | 5.04 | 5.65 | 6.29 | 6.97 | 7.69 | 8.43 | 9.21 | 10.0 | 10.9 | 6°00 |
| 10 | .29 | 45 | .65 | .88 | .15 | .45 | .79 | 17 | 58 | 3.03 | 52 | 4.03 | 58 | 18 | 80 | 46 | 7.16 | 7.90 | 66 | 46 | 3 | 11.2 | 10 |
| 20 | .29 | .46 | .67 | .91 | .18 | .49 | .84 | 23 | 65 | 11 | 61 | 14 | 71 | 32 | 5.96 | 64 | 35 | 8.11 | 8.90 | 72 | 6 | 5 | 20 |
| 30 | .30 | .47 | .68 | .93 | .21 | .53 | .89 | 29 | 72 | 19 | 71 | 24 | 83 | 46 | 6.12 | 81 | 55 | 33 | 9.13 | 9.97 | 10.9 | 11.8 | 30 |
| 40 | .31 | 48 | .70 | .95 | .24 | .57 | .93 | 34 | 79 | 28 | 80 | 35 | 4.95 | 60 | 27 | 6.99 | 74 | 54 | 36 | 10.2 | 11.2 | 12.1 | 40 |
| 50 | .32 | .50 | .72 | .98 | .27 | .61 | 1.98 | 40 | 86 | 36 | 90 | 46 | 5.08 | 74 | 43 | 7.16 | 7.93 | 75 | 60 | 4 | 4 | 4 | 50 |
| 7°00 | 0.33 | 0.51 | 0.73 | 1.00 | 1.30 | 1.65 | 2.03 | 2.46 | 2.93 | 3.44 | 3.99 | 4.57 | 5.20 | 5.88 | 6.59 | 7.33 | 8.13 | 8.96 | 9.83 | 10.7 | 11.7 | 12.7 | 7°00 |
| 10 | .33 | .52 | .75 | .02 | 33 | .69 | .08 | 52 | 3.00 | 52 | 4.09 | 68 | 32 | 6.02 | 74 | 50 | 32 | 9.17 | 10.1 | 10.9 | 12.0 | 13.0 | 10 |
| 20 | .34 | .53 | .77 | .05 | .36 | .73 | .13 | 58 | 07 | 60 | 18 | 79 | 45 | 16 | 6.90 | 68 | 51 | 38 | 3 | 11.2 | 12.2 | 3 | 20 |
| 30 | .35 | .54 | .79 | .07 | .39 | .77 | .18 | 64 | 14 | 68 | 28 | 4.90 | 57 | 30 | 7.05 | 7.85 | 71 | 60 | 6 | 5 | 5 | 6 | 30 |
| 40 | .36 | .55 | .80 | .09 | 43 | .81 | .22 | 69 | 21 | 77 | 37 | 5.01 | 70 | 44 | 21 | 8.02 | 8.90 | 9.81 | 10.8 | 11.7 | 12.8 | 13.9 | 40 |
| 50 | .36 | .57 | .82 | .12 | 46 | .85 | .27 | 75 | 28 | 85 | 47 | .12 | 82 | 57 | 36 | 20 | 9.09 | 10.0 | 11.0 | 12.0 | 13.0 | 14.2 | 50 |
| 8°00 | 0.37 | 0.58 | 0.84 | 1.14 | 1.49 | 1.89 | 2.32 | 2.81 | 3.35 | 3.93 | 4.56 | 5.23 | 5.95 | 6.71 | 7.52 | 8.37 | 9.28 | 10.2 | 11.2 | 12.3 | 13.3 | 14.5 | 8°00 |
| 10 | 37 | .59 | 86 | .16 | .52 | .93 | .37 | 87 | 42 | 4.02 | 66 | 33 | 6.07 | 85 | 67 | 54 | 47 | 4 | 1.4 | 5 | 6 | 14.8 | 10 |
| 20 | .38 | .60 | .87 | .19 | .55 | 1.97 | .42 | 93 | 49 | .10 | 75 | 44 | 20 | 6.99 | 83 | 72 | 66 | 7 | 7 | 12.8 | 13.9 | 15.1 | 20 |
| 30 | .39 | .61 | .89 | .21 | .58 | 2.01 | .47 | 2.99 | 56 | 18 | 85 | 55 | 32 | 7.13 | 7.98 | 8.89 | 9.86 | 10.9 | 11.9 | 13.1 | 14.2 | 4 | 30 |
| 40 | .40 | .62 | .91 | .23 | .61 | .05 | .51 | 3.04 | 63 | 26 | 4.94 | 66 | 44 | 27 | 8.14 | 9.07 | 10.1 | 11.1 | 12.1 | 3 | 5 | 15.7 | 40 |
| 50 | .41 | .64 | .92 | .26 | .64 | .09 | .56 | 10 | 70 | 34 | 5.03 | 77 | 87 | 40 | 29 | 24 | 2 | 3 | 4 | 5 | 14.7 | 16.0 | 50 |
| 9°00 | 0.42 | 0.65 | 0.94 | 1.28 | 1.67 | 2.13 | 2.61 | 3.16 | 3.77 | 4.42 | 5.13 | 5.87 | 6.69 | 7.54 | 8.45 | 9.41 | 10.4 | 11.5 | 12.6 | 13.8 | 15.0 | 16.3 | 9°00 |
| 10 | .42 | .66 | .96 | .31 | .70 | .17 | .66 | 22 | 83 | .50 | 22 | 5.98 | 81 | 68 | 60 | 58 | 6 | 11.7 | 12.8 | 14.0 | 3 | 6 | 10 |
| 20 | .43 | .68 | .98 | .33 | .73 | .21 | .71 | 28 | 90 | 58 | 32 | 6.09 | 6.93 | 82 | 76 | 73 | 10.8 | 12.0 | 13.1 | 3 | 5 | 16.8 | 20 |
| 30 | .44 | .69 | .99 | .36 | .76 | .25 | .76 | 33 | 3.97 | 66 | 41 | 20 | 7.06 | 7.96 | 8.91 | 9.90 | 11.0 | 2 | 3 | 6 | 15.8 | 17.1 | 30 |
| 40 | .45 | .70 | 1.01 | .38 | .80 | .28 | .80 | 39 | 4.04 | 74 | 50 | 31 | 18 | 8.10 | 9.07 | 10.2 | 2 | 4 | 5 | 14.9 | 16.1 | 4 | 40 |
| 50 | .46 | .72 | .03 | .41 | .83 | .32 | .85 | 45 | .11 | 82 | 59 | 42 | 30 | 24 | 22 | 3 | 4 | 6 | 13.8 | 15.0 | 3 | 17.6 | 50 |
| 10°00 | 0.47 | 0.73 | 1.05 | 1.43 | 1.86 | 2.36 | 2.90 | 3.51 | 4.18 | 4.90 | 5.69 | 6.52 | 7.42 | 8.38 | 9.38 | 10.5 | 11.6 | 12.8 | 14.0 | 15.3 | 16.6 | 18.0 | 10°00 |
| 10 | .47 | .74 | .07 | .45 | .89 | .40 | 2.95 | 57 | .25 | 4.99 | 78 | 63 | 54 | 52 | 53 | 7 | 11.7 | 13.0 | 2 | 5 | 16.9 | 3 | 10 |
| 20 | .48 | .75 | .08 | .48 | .92 | 44 | 3.00 | 63 | .32 | 5.07 | 88 | 74 | 67 | 66 | 69 | 10.8 | 11.9 | 2 | 5 | 15.8 | 17.2 | 6 | 20 |
| 30 | .49 | .76 | .10 | .50 | 95 | .48 | .05 | 69 | .39 | 15 | 5.97 | 85 | 79 | 80 | 9.84 | 11.0 | 12.1 | 4 | 7 | 16.1 | 5 | 18.9 | 30 |
| 40 | .49 | .77 | .12 | .52 | 1.98 | .52 | 09 | 75 | .46 | 23 | 6.07 | 6.96 | 7.91 | 8.94 | 10.0 | 2 | 3 | 6 | 14.9 | 3 | 17.8 | 19.2 | 40 |
| 50 | .50 | .79 | .13 | .55 | 2.01 | .56 | .14 | 81 | 53 | .31 | 16 | 7.07 | 8.03 | 9.07 | 2 | 3 | 5 | 13.8 | 15.2 | 5 | 18.0 | 5 | 50 |
| 11°00 | 0.51 | 0.80 | 1.15 | 1.57 | 2.04 | 2.60 | 3.19 | 3.87 | 4.60 | 5.39 | 6.26 | 7.17 | 8.16 | 9.21 | 10.3 | 11.5 | 12.7 | 14.0 | 15.4 | 16.8 | 18.3 | 19.8 | 11°00 |
| 10 | .51 | .81 | .17 | .59 | .07 | .64 | 24 | 93 | 66 | 48 | 35 | 28 | 28 | 35 | 5 | 7 | 12.9 | 3 | 6 | 17.0 | 6 | 20.1 | 10 |
| 20 | .52 | .82 | .18 | .62 | .10 | .68 | 29 | 3.99 | 73 | 56 | 45 | 39 | 40 | 49 | 6 | 11.8 | 13.1 | 5 | 15.9 | 3 | 18.8 | 4 | 20 |
| 30 | .53 | .83 | .20 | .64 | .13 | .72 | 34 | 4.05 | 80 | 64 | 54 | 50 | 53 | 63 | 8 | 12.0 | 13.3 | 7 | 16.1 | 6 | 19.1 | 20.7 | 30 |
| 40 | .54 | .84 | .22 | .66 | .17 | .75 | 38 | .10 | 87 | 72 | 63 | 61 | 65 | 77 | 10.9 | 2 | 5 | 14.9 | 3 | 17.8 | 4 | 21.0 | 40 |
| 50 | .55 | .86 | .23 | .69 | .20 | .79 | 43 | 16 | 4.94 | 80 | 73 | 72 | 77 | 9.91 | 11.1 | 3 | 7 | 15.1 | 5 | 18.0 | 6 | 3 | 50 |
| 12°00 | 0.56 | 0.87 | 1.25 | 1.71 | 2.23 | 2.83 | 3.48 | 4.22 | 5.01 | 5.88 | 6.82 | 7.82 | 8.89 | 10.0 | 11.2 | 12.5 | 13.9 | 15.3 | 16.7 | 18.3 | 19.9 | 21.6 | 12°00 |
| 10 | .56 | .88 | .27 | .73 | .26 | .87 | .53 | 28 | 08 | 5.97 | 6.92 | 7.93 | 9.01 | 2 | 4 | 7 | 14.0 | 5 | 16.9 | 5 | 20.2 | 21.9 | 10 |
| 20 | .57 | .89 | .28 | .76 | .29 | .91 | 58 | 34 | 15 | 6.05 | 7.01 | 8.04 | 14 | 3 | 5 | 12.8 | 2 | 7 | 17.2 | 18.8 | 4 | 22.2 | 20 |
| 30 | .58 | .90 | .30 | .78 | .32 | .95 | 63 | 40 | 22 | 13 | .11 | 15 | 26 | 5 | 7 | 13.0 | 4 | 15.9 | 4 | 19.1 | 20.7 | 5 | 30 |
| 40 | .59 | .91 | .32 | .80 | .35 | 2.99 | 67 | 45 | 29 | 21 | 20 | 26 | 38 | 6 | 11.9 | 2 | 6 | 16.1 | 6 | 3 | 21.0 | 22.8 | 40 |
| 50 | .60 | .93 | .34 | .83 | .38 | 3.03 | 72 | 52 | 36 | 29 | 30 | 37 | 51 | 8 | 12.0 | 4 | 14.8 | 3 | 17.9 | 5 | 2 | 23.1 | 50 |
| 13°00 | 0.61 | 0.94 | 1.36 | 1.85 | 2.41 | 3.07 | 3.77 | 4.57 | 5.43 | 6.37 | 7.39 | 8.47 | 9.63 | 10.9 | 12.2 | 13.6 | 15.0 | 16.5 | 18.1 | 19.8 | 21.5 | 23.4 | 13°00 |
| 10 | .61 | .95 | 38 | .87 | .44 | .11 | 82 | 63 | 50 | 46 | 49 | 58 | 75 | 11.1 | 3 | 8 | 1 | 16.7 | 3 | 20.0 | 21.8 | .7 | 10 |
| 20 | .62 | .97 | 40 | .90 | 47 | .15 | 87 | 69 | 57 | 54 | 58 | 69 | 9.88 | 2 | 5 | 13.9 | 3 | 17.0 | 6 | 3 | 22.1 | 23.9 | 20 |
| 30 | .63 | .98 | .41 | .92 | .50 | .19 | 92 | .75 | 64 | 62 | 68 | 80 | 10.0 | 3 | 6 | 14.1 | 5 | 2 | 18.8 | 6 | 4 | 24.2 | 30 |
| 40 | .63 | .99 | .43 | .94 | .54 | .22 | 3.96 | 80 | 71 | 70 | 77 | 8.91 | .1 | 5 | 8 | 3 | 7 | 4 | 19.0 | 20.8 | 7 | 5 | 40 |
| 50 | .64 | 1.01 | .45 | .97 | .57 | .26 | 4.01 | 86 | 78 | 78 | 86 | 9.02 | .3 | 6 | 12.9 | 4 | 15.9 | 6 | 3 | 21.0 | 22.9 | 24.8 | 50 |
| 14°00 | 0.65 | 1.02 | 1.47 | 1.99 | 2.60 | 3.30 | 4.06 | 4.92 | 5.85 | 6.86 | 7.95 | 9.12 | 10.4 | 11.7 | 13.1 | 14.6 | 16.1 | 17.8 | 19.5 | 21.3 | 23.2 | 25.1 | 14°00 |
| 10 | .65 | .03 | .49 | 2.01 | .63 | 34 | 11 | 4.98 | 92 | 6.95 | 8.05 | 23 | 5 | 11.9 | 2 | 8 | 3 | 18.0 | 19.7 | 21.5 | 5 | 4 | 10 |
| 20 | .66 | .05 | .50 | .04 | .66 | .38 | 16 | 5.04 | 5.99 | 7.03 | 14 | 34 | 6 | 12.0 | 4 | 14.9 | 5 | 2 | 20.0 | 21.8 | 23.7 | 25.7 | 20 |
| 30 | .67 | .06 | .52 | .06 | .69 | .42 | 21 | .10 | 6.06 | 11 | 24 | 45 | 8 | 1 | 5 | 15.1 | 7 | 4 | 2 | 22.1 | 24.0 | 26.0 | 30 |
| 40 | .68 | .07 | .54 | .08 | .72 | 45 | 25 | 15 | .13 | 19 | 33 | 56 | 10.9 | 3 | 7 | 3 | 16.9 | 6 | 4 | 3 | 3 | 3 | 40 |
| 50 | .69 | .09 | .56 | .11 | .75 | 49 | 30 | 21 | .20 | 27 | 43 | 67 | 11.0 | 4 | 13.8 | 4 | 17.1 | 18.8 | 6 | 5 | 5 | 6 | 50 |
| 15°00 | 0.70 | 1.10 | 1.57 | 2.13 | 2.78 | 3.53 | 4.35 | 5.27 | 6.27 | 7.35 | 8.54 | 9.77 | 11.1 | 12.5 | 14.0 | 15.6 | 17.3 | 19.0 | 20.8 | 22.8 | 24.8 | 26.9 | 15°00 |
| | 80 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 | 260 | 280 | 300 | 320 | 340 | 360 | 380 | 400 | 420 | 440 | 460 | 480 | 500 | |

Degree of Spiraled Curve.

Length of Spiral.



Computations

$\frac{534.4}{\sin 45^\circ} \times \sin 50^\circ = 579.0'$

$\frac{534.4}{\sin 45^\circ} \times \sin 5^\circ = 65.9'$

Distance from new P.I. to Original Center Line opposite $= 460 \div 5 = 92'$ (460.0' = Ext Dist for 1° Curve for Δ = Central angle of original curve up to that point)

92.0' — probable value of $\left(\frac{E}{\cos\frac{\Delta}{2}} + \frac{E}{2}\right) = 85.8'$

Degree for spiraled curve $= 472.11 \div 85.8 = 5.5$ (472.11' = Ext. Dist for 1° Curve, Δ = 45°)

Tang. Dist (Δ = 45°, D = 5.5 = 5°30') = 431.4'

Spiral Offset (L = 300', D = 5°30') = 35.9'

Curve throws out at Center by amount $92' - \left(85.8' + \frac{35.9}{\cos 22°30'}\right) = 2.3'$

Computations

$\frac{521.4}{\sin 35^\circ} \times \sin 40^\circ = 584.3$

" $\times \sin 5^\circ = 79.2$

Dist from new P.I. to Original Center Line opposite = 267.17 (Ext. Dist for 1° Curve for Δ = Central angle of original Curve up to that point) divided by 4 = 66.29'

66.29 — probable value $\left(\frac{E}{\cos\frac{\Delta}{2}} + \frac{E}{2}\right) = 63.2$

Degree for Spiraled Curve $= \frac{278.07}{63.2} = 4.4 = 4°24'$ (278.07 = Ext Dist for 1° Curve, Δ = 35°)

Tang Dist. (Δ = 35°, D = 4°24') = 410.6

Spiral Offset (L = 240, D = 4°24') = 1.84

Curve throws out at center $66.29 - \left(63.2 + \frac{1.84}{\cos 17°30'}\right) = 1.2$

Figure 9.

probably find a runoff of perhaps 250 feet in length, beginning at "B' and extending back 217 feet on the curve.

In spiraling this curve, as shown in the upper part of Fig. 5, it is changed to a 5° 17′ curve, and the new P. C. is 27 feet back of the old, or 60 feet from the end of the bridge, leaving 90 feet of the runoff on the bridge, and making a throw for the track at the end of the bridge of 0.108 F = 0.37 feet; at a point 30 feet on the bridge of 0.032 F = 0.11 feet; and at a point 60 feet on the bridge of 0.004 F = 0.01 feet. The super-elevation decreases proportionately with the distance to zero, 90 feet on the bridge. The necessary throw can usually be made by moving the rails on the ties (spike-lining), and the necessary super-elevation can be introduced by spiking elevation blocks or shims on the ties under the outer rail.

In spiraling a railroad curve on maintenance work, where a bridge, a railroad crossing, a depot platform or any other condition compels the engineer to leave the line in its existing position at any part of its length, some arrangement can always be found to allow him to obtain a spiraled line, even with such conditions. He should not be defeated in an attempt to spiral every curve on the railroad, of whatever description.

The salient points to be remembered in connection with the transition spiral are:

1. In order to adjust a curve so as to obtain the best possible riding quality for fast trains using the tracks thereon, it must be spiraled.

2. It is little, if any, more difficult or expensive to set stakes for the center line for a spiraled curve than for an unspiraled one.

3. It is little, if any, more difficult or expensive to construct a new railroad on a line of spiraled curves than otherwise.

4. It is always possible on old track to add spirals to the curves by throwing them so little as to be quite inexpensive. This will be especially true if the spirals are added while other work, such as extensive ballasting or double tracking, is being done.

5. It is not necessary for the engineer to have a special field book for his use in spiraling curves—any field book containing tables of natural sines and tangents will be sufficient.

6. The most important point of all, is to see that after the spiraled center line is staked out and track is being made to conform to it, for line, it must not be forgotten to see that the ends of the super-elevation runoff are made by the trackmen to conform exactly with the ends of the spiral, and that the change from zero at one end to the full super-elevation for body of the curve at the other is obtained proportionately with the distance from the zero

end. Monuments should always be marked with the super-elevation and set in the sod line for reference by the trackmen for future maintenance.

### DISCUSSION.

*R. P. Morgan (by letter)* Of the six "salient points" laid down by Mr. Torrance I concede all except the first.

That point involves the question itself and is laid down as an ascertained truth, a maxim, i. e., "a curve must be spiraled to get the best results."

The impressions on my mind now are that the proofs of the necessity for transition spirals or any other compounding laterally of the ends of curves are themselves as yet transitory and somewhat nebulous.

I may also say, perhaps safely, that the transition spiral in the alignment of railway tracks may possibly be a theoretical illusion, a kind of conundrum in the science of Civil Engineering, possessing no practical value.

One fact worthy of note in this connection is that the passenger trains on the Hudson River Railroad, which is somewhat noted for its curvature, made in 1852, 50 years ago, a card speed of about 40 miles an hour, including stops, and the trains often made runs of as much as 60 miles an hour. Two of the locomotives then in use had 6½-feet drivers and were warranted to make a speed of 80 miles an hour.

Another fact is that no "transition spirals" were then employed, nor were rigid angle bar joint fastenings in use, but instead the simple wrought iron lip chair.

For laying and maintaining track at that time, the instructions from the Engineering Department were, in substance, that when the leading truck of a train entered upon a curve, the outside rail having gradually risen on the tangent so that the center of gravity of the locomotives or cars properly met the centrifugal force exerted after passing the tangent point, the problem of smooth movement was practically solved.

The excellent and "most important point of all," urged by Mr. Torrance, the sixth, applies with equal force to the method of laying and maintaining tracks in 1852; but in either case, spiraled or not, the adjustment of the entrances upon and throughout a curve is established upon a specific speed basis, therefore it must be in a measurable degree defective in respect to higher or lower velocities and other conditions in detail. Hence the sixth point, a provision for and the perfect maintenance of the track, with or without spiraling, will doubtless give excellent practical results.

But as yet the conclusion of Mr. Torrance that "to obtain the best possible riding quality for fast trains, the curves must be spiraled," seems to need additional proof in both theory and practice.

*A. M. Haynes (by letter)*—I would call attention to what I consider a defect; a defect which is common and fatal. I know that others will not agree with me, but they will concede that difficulties are encountered in making the length of spiral conform with a standard "run-off." The only necessity given for a standard run off is that it is easy for trackmen. They can remember (so it is said) to raise each succeeding rail ½ inch higher, or some other uniform distance per 30′ rail. There should be a maximum rate of run-off, but below that it should conform with the length of spiral, whatever that may be. In the past ten years I have seen several systems of spirals devised and put in operation successfully on easy alignment, but when it came to the rough part of the road where needed the most, they could not be put in. Curves became too sharp and plentiful, and too close together. Notes get mixed under the most favorable circumstances. The alignment cannot be picked up readily after the work becomes cold and the tables and formulæ not easily identified.

My remedy would be a standard spiral of the same number of chords and with the same deflections in all cases.

I would make the length of those chords (being 100 feet for a 1-degree curve) vary with the length of the main curve, that is, inversely as the degree. Then all the functions of the spiral and of the spiral and circular curve combined will be inversely as the degree of the main curve.

Then we can dig out our old tables of semi-tangents, externals, etc., of a 1-degree curve for all angles, add constants to the quantities found, and divide by the degree of the main curve to obtain all the distances that may be desired, in connection with the combined curve, just as we used to do in using simple circular curves. But there is the objection that it does not fit a standard run-off. Any one can see that, but the more serious objections in other plans are not so discernible—objections which have prevented the use of any easement in some places, where they are most needed.

This plan was first described in the Journal of the Associated Engineering Societies in December, 1894, and has been thoroughly tried on new location and in improving old track and where 8-degree curves were thick. In years to follow the alignment can be readily understood from the right-of-way map without studying field notes. And such a map would have no more notes than the old-fashioned maps, except that the stations at ends of spirals would be given and a general notation that all curves are spiraled with the following deflections from tangent and all the same whole angle.

*Willard Beahan (by letter)*—We will have spiraled curves, in my judgment, just as soon as Civil Engineers are responsible for the riding qualities of the track. Track foremen have always tended to throw the track *in* at the ends and *out* at the center on short, sharp curves. They introduced the spiraled curve unconsciously. The result was approximate, but the improvement in the riding qualities was plain. The Civil Engineer should learn of the track foreman and spiral curves just as the civil engineer has taken the hint from the engineman and removed train stops from sags in the grade line, and learned to give no heed to low summits on a grade line, but depend on the train velocity to overcome the increase in tractive pull. A spiraled curve and a virtual profile are alike refinements in railroading. They belong properly to maintenance of way, in the main. They are useful. They may be abused by their friends but they cannot be safely ignored by their enemies. Neither are panaceas. Each is an adjunct to economy in operating and efficiency of service of the road.

The history of a curve on the Lehigh Valley Railroad at Kennedy Station in New Jersey shows in a practical way the effect of spirals. The curve is a short one but sharp for that locality. As I recollect it, the length is 1,000 feet, and it is a 4-degree curve. The Black Diamond Express train passes over the curve on the west-bound track often at a speed of 75 miles an hour. That part of the road was built 25 years ago. There was for a very long time a special rule on all employees' time cards requiring all passenger trains to slow down for that curve. It had been relined a few years ago by the late Richard Caffrey, then General Roadmaster of the road and an excellent trackman, particularly on alignment. When rock ballasting the line at that point in 1899, I obtained permission to spiral the Kennedy curve. Mr. Torrance did the work and I think used a spiral some 240 feet long. The center line and superelevation were carefully put in and monuments set. The track was watched and checked until the ballast was to a firm bearing. Nothing was said to the trainmaster or enginemen, and this was the first curve spiraled on that division. The enginemen found that the Kennedy curve was riding well at full speed and ceased to slow down for it. Noticing this, the trainmaster took them to task for it. They claimed that for some reason the curve was riding so well, slowing down was not necessary. The trainmaster rode over the curve several times to investigate. He asked me what had been done to that curve. I made no reply. He took the special rule off the time card. I then told him what had been done. The Kennedy curve was never an obstruction to speed from that time until I left the road.

Permission was then granted us to spiral all curves when putting in rock ballast, provided we did so without getting the track off the roadbed. This Mr. Torrance was able to do by the method shown in this paper. Even at depots and water cranes, which made a fixed point in the center line, he was able to do this for that part of the line. Much can be done with small outlay if we have experience in this work. The engineering field work needs but three men, and for any usual curves but a few hours are needed.

In my judgment, a strong reason why spiraled curves have not been introduced on many roads is because these curves have been studied in an academic rather than a practical way. We have talked and thought cubic parabola rather than easy riding track. A spiral in railroad alignment is a means, not an end. We are trying to ease our jolts. We have used too complicated formulæ or too bulky tables. We have often found the curve hard to compute and have kept it so until we need to go back to college a half term to master our spiral curve. Many engineers would today use spiraled curves were it not so hard to use the methods or so necessary to carry a special handbook. All this is wrong. We must keep close to the trackman in track matters. Never cherish the purity of the cubic parabola for its own sake. In my own case the spiral was hard to compute at first, but we were doing it in leisure time in a locating camp, and none of us had ever heard of such a curve in that connection. But when the spiral was once computed we continued until we had it in a form easily used. Very little field computation was needed, and the entire table for one spiral was pasted on a flyleaf of a Butts' Field Book for Locating Engineers. Not over three different spirals are needed on location, and we used but one. On maintenance all that is needed is the method shown in the paper. It seems to me that this paper is a distinct service to the profession in that it has made the subject less complicated. His method is known by me to be easy of application and ingenious in many ways. Several of these devices and functions are original with or found out by him.

Relative to the cost of the engineering work of spiraling curves for a line on location, we found that it cost about 1 per cent additional per mile of located line. In a conversation with the Chief Engineer of the Southern Pacific Railway he told me that putting spirals on curves cost on an average $1.00 per mile of located line. His company have done this for years. Is there anywhere else in railroad work where more benefit can be derived from that outlay? To put in spirals on maintenance is much more expensive, for the track must be shifted. To do this when ballasting with rock is comparatively cheap. Of course the spirals tend to shift the central part of the original curve *in*. It might seem that this fact prohibits the spiraling of curves of much length. But if the original curve be modified a little by sharpening its degree a minute or two, or in some cases a fraction of a minute, the track can be kept on the roadbed. In Mr. Torrance's work on the Lehigh Valley R. R. he so fitted the spiral curve to the conditions that not even the longest curves, so sharp that long spirals must be used, were shifted enough to require a widening of the roadbed.

To put spirals at the ends of circular curves is primarily a question of trigonometry, but it is finally a question of track work and should be so considered. It needs a little time for the civil engineer to set the new center line stakes, but far less time than most of us now use in doing it. It costs little on location. It need not cost enormously on maintenance if we select an opportunity. It always costs something to shift track, and it costs to tamp it to a surface and hold it there to line and elevation. But this cost is at points most expensive to even maintain and where improvements in the riding qualities of the track are very desirable. This paper serves the purpose of showing us how to save our own labor and to do more good to the track for the same outlay of track labor.

*Prof. A. N. Talbot (by letter)*—The subject of Mr. Torrance's' article has interested the writer for many years, and the paper is of timely interest now that so many railroads are making large expenditures on permanent way and adding to the comfort and safety of passengers on fast trains. The article presents the advantages of inserting spirals or easements at the ends of circular curves and testifies to the ease with which such spirals may be maintained. It states some of the properties and methods of application of one of the best transition curves.

The advantage gained in the gradual and easy attainment of the superelevation required for the circular curve by means of the transition spiral, allowing this superelevation to be kept proportional to the varying curvature, is quite generally appreciated. Other causes contribute to the resulting good riding qualities of curves properly spiraled. The trucks are gradually swung to a new position with respect to the car body, the couplers are adjusted to the new position, the springs have the additional pressure brought gradually upon them, and all without an accompanying jerk. These effects are independent of whether the superelevation exactly counteracts the effect of the centrifugal force or not.

The writer believes that very short spirals are overrated. The spiral cannot perform feats of magic, and the results reported for very short spirals in some quarters must be due principally to realignment, and may probably be obtained without the spiral by running the superelevation back on the tangent an equal distance. The spiral should certainly vary enough from the position of a circular curve that the distinction may not be obliterated by the inaccuracies of track work. The amount of this divergence may easily be judged by taking one-half of the offset F, since this gives the distance from the spiral to the offsetted curve at the middle point of the spiral. The lengths of spiral proposed some years ago by the writer as desirable lengths have been commended by engineers in charge of maintenance of way. These lengths may be expressed in terms of the distance in which a degree of curve is attained and for the maximum rates of speed at which trains are to be run: 60 miles per hour, 1 deg. in 200 ft.; 50 miles per hour, 1 deg. in 100 ft.; 40 miles per hour, 1 deg. in 50 ft.; 30 miles per hour, 1 deg. in 30 ft. Spirals half the length of these have given gratifying results, and it is not always practicable to obtain lengths as great as these. One may get an idea of the gain in making long spirals by seeing that in the short time taken at high speeds to get over the spiral the car must be canted and the trucks and springs adjusted. The suggestion made by the writer that the proper length of spiral is nearly as the cube of the speed to be used calls attention to the desirability of long spirals for high speeds. For low speeds the adjustment of car to new curve conditions is of more importance than ease in attaining the superelevation.

The advantageous length for spirals and the permissible expenditure for their insertion ought to make a fruitful topic for discussion. To cite an example, a railroad in Pennsylvania which is making extensive changes and improvements has a double track 8 deg. curve beginning just within a tunnel. It is desired to spiral the curves for a train service of 40 miles per hour, necessitating the widening of a portion of the tunnel. What length of spiral shall be used? Another topic might be made out of the minimum length of tangent allowable between points of two spirals for curvature in the same or in opposite directions.

In the selection of length of spiral and the choice of method for field work, it would seem that the rate of attainment of curvature is on the whole the most advantageous element to talk about and to place on the record. On one portion of a division, spirals attaining 1 deg. in a given length may be used; on another, the length of spiral may be different; and this plan is convenient for both record and field work. The plan of basing the length of spiral on the distance in which the superelevation is to be attained has some advantages, but the amount of the superelevation is generally decided rather arbitrarily, and a new management or changed conditions may modify it, and practice concerning it is continually changing. For this reason the rate of gaining curvature is a better factor, and the number of degrees of curve gained in 100 ft. of spiral or the number of feet to get 1 deg. of curve the term to be used. By the foregoing it is not meant that rate of attainment of superelevation should not be considered in determining the desirable length of spiral, but that it should not be made the principal variable.

As stated in the paper, the application of the transition spiral to new lines is easy, and in general the cost of construction is but little increased even for long spirals. The methods for old lines given in the plates are in general quite convenient. However, the method of making the length of spiral that which will make a given offset has been criticised by engineers as tending to make too great a variety of curves. In view of the importance of applications to old track, it would be well to outline the methods of procedure more fully.

The author does not attempt to demonstrate the mathematical properties of the transition spiral, but instead illustrates the principles and shows their applicability. The attention of the indifferent reader should be called to this fact, that he may not take illustrations and statements of properties to be easy demonstrations, or some of the approximate properties to be precise values. The illustrations and statements of properties given are none the less valuable for this reason.

It seems to the writer that the author falls into an error (one not infrequently made) when he apparently bases his properties on the approximation that the sine is proportional to the angle. This approximation of itself would fail long before the limits given in the table are reached. The use of the length of curve instead of the chord nearly neutralizes the error. The errors are compensating rather than cumulative, but the closeness of this compensation cannot be shown by the methods indicated in the paper. That the above does not refer to unpractical matters may be seen by realizing that for the limit given in the table, 500 ft. and 15 deg. curve, the long chord differs from the length of spiral by 9.3 feet, and half the central angle varies 21′ from an angle whose sine is considered proportional to the angle. In other words, the formulas and principles used are correct, or approximately so, but the methods of deducing them are inaccurate.

The same criticism may be made of the derivation of the formula

$$F = \frac{L}{6} \sin \left(\frac{L}{100} D\right).$$

This formula is a very convenient form and expresses the value of the offset very accurately even for long spirals, and Mr. Torrance is entitled to our thanks for bringing it out. The method of deriving it by taking one-third of the perpendicular distance from tangent through P. C. to the point P S$_2$, while it may be of service in the way of illustration, is not proper for demonstration. To show this, take the limit of the table, 500 ft. and 15 deg. curve.

The offset by this formula is 26.8 ft., which is almost exactly the right value. The value of the perpendicular distance referred to is actually 78.9 ft., while three times F is 80.4 ft., which would cause an offset in alignment of 1.5 ft. While this may be said to be an extreme case, yet the formula for F is so accurate that it should not be based on a crude approximation.

Again, the distance along the tangent from a point opposite P. C. to P. S. is indicated as one-half the length of the spiral. For many applications this is quite accurate, but for others a correction would need to be made. In the middle diagram of Fig. 6 this half length is 1 ft. longer than the desired distance. For the spiral 500 ft. long to connect with 15 deg. curve, the limit given in the table of offsets, the half length of spiral is 3.6 ft. too long. For 500 ft. and a 5 deg. curve, it is 0.4 ft. too long. Inaccuracies in other directions will be found for spirals of some length.

The writer does not raise the above points because he discredits short cuts or approximate solutions; on the other hand he favors the use of such, and he considers that approximate demonstrations serve as illustrations and aid in grasping new conceptions; but he believes that it is well to establish underlying principles and that it is well to state approximate formulas in such way that the error may easily be determined.

Other properties of the transition spiral which it may be convenient to have are long chord, spiral tangent distance, abscissa and ordinate, and middle ordinate. Fortunately these are not complicated functions, and the excess of the length of spiral over that of the long chord, the abscissa, and the terminal spiral tangent are so closely related that one may be determined from another.

Concerning the question of the efficacy of transition curves raised in the discussion of the paper, it is safe to say that the verdict of observing engineers who have tried the maintenance of curves with and without easements is overwhelmingly in favor of such easements. Instances are not rare where well-lined curves failed to give satisfactory riding qualities, and when slow orders were given, until transition spirals were put in, when full speeds were permissible. The improved conditions are certified to by trainmen and passengers as well as by the civil engineer directing the work. Part of the advantages found by putting in spirals is undoubtedly due to realignment, and this realignment is more easily maintained when spirals are put in. If time permitted, abundant and convincing evidence of the efficacy of spirals could be collected.

The statement that the length of spiral must exactly suit the speed and that for any other speed the spiral is a bad misfit is an erroneous assumption. A given elevation of the outer rail will satisfactorily cover quite a range of speeds besides the rated speed, and even if this range of speed were small no one would think of abolishing elevation. But the basis of easement curves makes them useful over a still wider range of speed. If the easement is sufficiently long to allow the elevation to be properly and easily attained at the maximum speed, the effects at lower speeds, so far as ease of attainment of elevation is concerned, will be likewise advantageous. It must be borne in mind that centrifugal force is not usually exactly balanced by elevation of rail, and that the additional pressure on rail and springs is allowable if it is uniformly applied and steadily maintained.

It may even be said that horizontally the spiral is useful. The trucks must take a new position with respect to the car body, and the coupler is moved through an angle. With long cars and sharp curves this motion is appreciable, and part of the lurch on entering a curve must be due to the sudden attempt to adjust to the new conditions.

The principal easement curves in use give alignments which approach each other very closely, so that for equal easements it may be expected that the riding qualities will not differ sensibly. In general, ease of calculation, simplicity of field work and general applicability and flexibility will determine the form of easement curve to be selected. To establish the underlying principles of an easement curve of any range requires mathematical analysis. The ordinary treatment of circular railroad curves assumes previous knowledge of the geometrical properties of the circular curve, but the properties of the spiral must be deduced from the beginning. Fortunately, the spiral is not complex, and its properties prove to be simple and general. The range of conditions of railway curves is so wide that it is best to devolop methods of general applicability, and these may then be simplified in meeting individual conditions. Several treatments of the spiral are available, any one of which is satisfactory. For the ordinary range of length of spiral, many approximations are permissible, and the user soon gets many short cuts and easy solutions. His choice of method will depend largely upon his personal bent, but facility in application to problems involving existing curves, and certainty in the methods of transmitting records to his successors, should enter into the choice.

*Mr. A. A. Schenck (by letter)*—My experience with spiral curves began as a subordinate under Wm. H. Searles in 1882. I find among my papers numerous letters of correspondence and discussion with him, prior to the publication of his excellent book on spirals. Several years later I had opportunity when serving under Wm. Hood, Chief Engineer of the Southern Pacific Co. and in charge of the Santa Rosa & Carquinez Road, to contrast the spiral methods of Hood and Searles. Hood's spirals furnish what most railway engineers desire, a circular alignment at any and all points, so that by the methods of laying out circular curves, any and every point of the line can be exactly set by such methods and tangent and radius at such points found. Hood's method is practically a series of compound circular curves. I have used them in very difficult locations in swamps and broken ground, and nearly always with great ease, owing to the completeness of the tabulation and information given. Copies of these tables having been sent me by Mr. Hood subsequent to my leaving the Southern Pacific Company, and with no injunction against letting others benefit therefrom, I present the complete set herewith, and recommend that they be incorporated in the Society's papers. I add also a letter from Mr. Hood transmitting these tables.

Each of us has our preference. My own, after a study of the methods of Talbot, Howard, Crandall, Holbrook, Olmstead, Allen, Young, Echols, Geiseler, and J. S. Armstrong, is a preference for Hood's system. Beahan follows these, modified to suit local demand. If spirals or easement curves are to be used, I recommend Hood's system. They show at once on their face what they aim to be, without a large amount of explanatory literature being required.

But it will pay the Society to give close investigation to the question whether spirals amount to anything; and if so, just what. The opponent of spirals generally dreads being classed as unscientific, uneducated, of an old school of engineering, and a back number. The operating official looks at all the spiral schemes from another point of view. He wishes to see where the cash is to come in from their use and what the interest will be on the investment. By keying himself up to it, he is willing to accept from the scientific men even a scientific reason and demonstration of the usefulness of spirals; but he wants some demonstration. He claims that the mathematician is more attentive to his processes than to his premises, and that no spiral enthusiast has yet proven the gain from spirals. It is well, lawyer fashion, for us to put ourselves in the position of antagonist and consider carefully the arguments of the opponents. They are these:

1st. Spirals do not help a moving train, or motion of any sort, to run in a circular direction. Motion ever tends to tangent and is as much "on tangent" when it has reached a heavy curve direct from tangent as when supposed to be coddled into curvature by an attempted spiral. The common popular reason for a spiral has no foundation in natural law. Horizontally, the spiral is absolutely useless.

2nd. Lateral elevation does not depend on degree of curvature alone, and is not helped out of a misfit into a perfect fit by any spiral ever invented. Lateral elevation is dependent, not on one factor, viz., degree of curve, but on two factors, curvature and speed. The road most perfectly spiralled for one degree of speed is a bad misfit for all other speeds in spite of any possible amount of money spent. This misfit for some speeds and curves on the spiral is greater than caused by laterally elevating a tangent for other speeds at other curves. Many of our spiral systems are based only on a fixed amount of lateral elevation per degree of curve. Speed, and variations of speed due to gradients, length of gradient, proximity of stations and crossings, etc., are not noted in these systems; hence the misfit, the overvaluation of spirals and the supposed perfection of roadbed and train movement that exists only in the mind of the enthusiast. Examples may be taken of the extent of misfit in spirals and the amount of misfit shown to be many times as great there on a spiral as on "tangent approaches" to curves. A tabulated statement of misfits on spirals and of misfits on "tangent approaches," for various speeds, is interesting for comparison.

A 4-degree curve may be spiralled to give the correct curvature to suit lateral elevation for 50 miles per hour, or say 6¾ inches. For 10 miles per hour this lateral elevation (and amount of consequent spiralling) should be only about ¼ inch or less. Hence for such speed of 10 miles the error or misfit is 26 times or more the lateral elevation of ¼ inch. The lurch of a passenger train happening to go slowly would be greater than on a tangent at an unspiralled curve having 4 inches lateral elevation. The former has 6½ inches too much elevation for the slow train, the latter only 4 inches too much theoretically, for another degree of curvature.

Since the usefulness of any special spiral is dependent on speed as well as curvature, and since the spiral is a correct fit only for one speed, we may assume safely as follows:

No engineer or other person can tell in the dark whether he is on a spiralled road or not.

No engineer or other person can tell in the dark whether he is on an unspiralled approach to a curve or on the curve itself near its beginning or end.

No engineer or other person can tell when on a spiral whether the train is running at the degree of speed for which the spiral is calculated and put in place.

No engineer or other person can tell whether any lurching on curve is due to lack of spiral or to lack of general good maintenance of line and surface of the curve.

Where good riding occurs on a spiralled road, it is due to general good maintenance. The use of spirals causes more frequent setting of line and levels by the engineer for the curve generally, and a road willing to spend money on spirals is also willing to spend money on maintenance generally, and has such maintenance irrespective of spirals. Hence it is not known whether easy riding on spiraled roads is due to spirals or to the general willingness to spend money for a higher grade of maintenance.

I present these counter-arguments to draw out, if possible, exact proof of the benefits claimed for spirals, and to learn how there is any such perfect fit resulting from their use as is claimed. It is time that spiralling engineers examined their premises and that they give reasons for the faith they have in spirals, and for the relations they assume between curvature, lateral elevation, *and speed.*

SOUTHERN PACIFIC COMPANY.
OFFICE OF CHIEF ENGINEER,
SAN FRANCISCO, Aug. 11, 1890.

*Archibald A. Schenck, Esq., Chief Asst. Engr., N. Y. C. & H. R. R. R. Co.*

DEAR SIR—Enclosed please find taper curve tables per your request of 5th inst.

We use Taper ½ wherever cost of construction will admit of it, and in general as flat tapers as cost of construction and tangent lengths will allow.

We never use Taper 4, unless on narrow gauge lines with 15 deg. or 20 deg. curves.

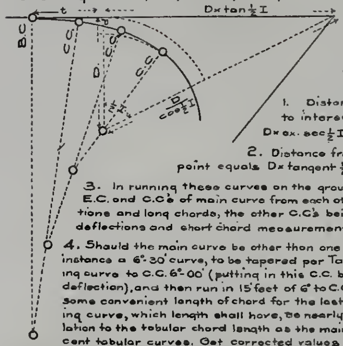
As you may remember, we hold tangent track level transversely to within 30 feet of B. C. or E. C.

Yours respectfully,
(Signed) WILLIAM HOOD.
Chief Engineer.

We very commonly use one sort of taper at one end and one at the other end of curve, where both such cannot conveniently use a flat taper, putting easiest one at the end likely to be struck at highest speed.

## DIAGRAM

Showing "D" "d," "t," of Tapering Curve Tables.



Let I equal intersection angle of tangents to curve then:—

1. Distance from middle of curve to intersection point equals. D×ex. sec½I+d, or $\frac{D}{\cos\frac{1}{2}I}$ − Radius of main (Curve)

2. Distance from B.C. to intersection point equals D×tangent ½I+t.

3. In running these curves on the ground it is best to fix the B.C. E.C. and C.C's of main curve from each other by the proper deflections and long chords, the other C.C's being put in by successive deflections and short chord measurements.

4. Should the main curve be other than one shown in the tables - for instance a 6°-30' curve, to be tapered per Table 2 - run in the tapering curve to C.C. 6°-00' (putting in this C.C. by tabular long chord and deflection), and then run in 15 feet of 6° to C.C. 6°-30' - in all cases taking some convenient length of chord for the last compounding of the tapering curve, which length shall have, as nearly as may be, the same relation to the tabular chord length as the main curve bears to the adjacent tabular curves. Get corrected values of D and t by multiplying cosine and sine of total curvature up to main curve by the difference of radii of main curve and of last branch of compound curve; subtract cosine product from D, and add sine product to t (as taken from the table for the last branch of the compound curve).

For Table ½.

| Degree of Main Curve | "D." | "t" | Total Curvature in Tapering Curve at Each End of Main Curve. | "d" = "D" less Radius of Main Curve. | Long Chord from B.C. of Taper to C.C. of Main Curve |
|---|---|---|---|---|---|
| ° ' | | | | ° ' | |
| 0-30 | 11459.18 | 15.00 | 0-04½ | 0-01 | 30.00 |
| 0-45 | 7639.49 | 30.00 | 0-13½ | 0-04 | 60.00 |
| 1-00 | 5729.70 | 45.00 | 0-27 | 0-10 | 90.00 |
| 1-15 | 4583.88 | 60.00 | 0-45 | 0-20 | 120.00 |
| 1-30 | 3820.09 | 75.00 | 1-07½ | 0-34 | 150.00 |
| 1-45 | 3274.63 | 90.00 | 1-34½ | 0-55 | 179.99 |
| 2-00 | 2865.65 | 104.99 | 2-06 | 0-83 | 209.99 |
| 2-15 | 2547.70 | 119.99 | 2-42 | 1-18 | 239.98 |
| 2-30 | 2293.50 | 134.98 | 3-22½ | 1-62 | 269.96 |
| 2-45 | 2085.69 | 149.97 | 4-07½ | 2-16 | 299.93 |
| 3-00 | 1912.72 | 164.95 | 4-57 | 2-81 | 329.89 |
| 3-15 | 1766.58 | 179.92 | 5-51 | 3-57 | 359.84 |
| 3-30 | 1641.55 | 194.88 | 6-49½ | 4-47 | 389.76 |
| 3-45 | 1533.45 | 209.84 | 7-52½ | 5-49 | 419.65 |
| 4-00 | 1439.14 | 224.77 | 9-00 | 6-67 | 449.51 |
| 4-15 | 1356.21 | 239.69 | 10-12 | 8-00 | 479.33 |
| 4-30 | 1282.82 | 254.59 | 11-28½ | 9-50 | 509.10 |
| 4-45 | 1217.48 | 269.47 | 12-49½ | 11-17 | 538.81 |
| 5-00 | 1159.03 | 284.31 | 14-15 | 13-03 | 568.45 |

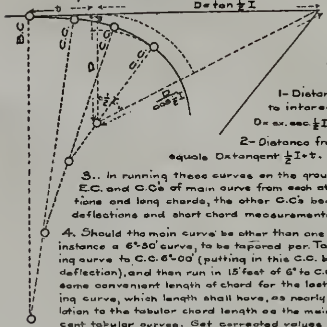
| RADII FOR 50 FT. CHORDS | | | |
|---|---|---|---|
| Degree | Radius | Degree | Radius |
| ° ' | | ° ' | |
| 0-15 | 22918.32 | 5-15 | 1091.45 |
| 0-30 | 11459.17 | 5-30 | 1041.84 |
| 0-45 | 7639.45 | 5-45 | 996.55 |
| 1-00 | 5729.60 | 6-00 | 955.04 |
| 1-15 | 4583.69 | 6-15 | 916.85 |
| 1-30 | 3819.75 | 6-30 | 881.59 |
| 1-45 | 3274.08 | 6-45 | 848.95 |
| 2-00 | 2864.83 | 7-00 | 818.64 |
| 2-15 | 2546.52 | 7-15 | 790.42 |
| 2-30 | 2291.88 | 7-30 | 764.08 |
| 2-45 | 2083.33 | 7-45 | 739.44 |
| 3-00 | 1909.91 | 8-00 | 716.34 |
| 3-15 | 1763.01 | 8-15 | 694.65 |
| 3-30 | 1637.09 | 8-30 | 674.22 |
| 3-45 | 1527.96 | 8-45 | 654.97 |
| 4-00 | 1432.47 | 9-00 | 636.78 |
| 4-15 | 1348.21 | 9-15 | 619.58 |
| 4-30 | 1273.32 | 9-30 | 603.29 |
| 4-45 | 1206.91 | 9-45 | 587.33 |
| 5-00 | 1146.01 | 10-00 | 573.14 |

## TABLE ½ – Tapering Curves Changing 0°-15' Each 30'

| TRANSIT AT | DEFLECTIONS TO | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B.C. 0°-15' | C.C. 0°-30' | C.C. 0°-45' | C.C. 1°-00' | C.C. 1°-15' | C.C. 1°-30' | C.C. 1°-45' | C.C. 2°-00' | C.C. 2°-15' | C.C. 2°-30' | C.C. 2°-45' | C.C. 3°-00' | C.C. 3°-15' | C.C. 3°-30' | C.C. 3°-45' | C.C. 4°-00' | C.C. 4°-15' | C.C. 4°-30' | C.C. 4°-45' | C.C. 5°-00' |
| | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' |
| B.C.-0-15 | ...... | 0-02¼ | 0-05¾ | 0-10½ | 0-16¾ | 0-24¾ | 0-34¼ | 0-45 | 0-57½ | 1-11¼ | 1-26¾ | 1-43½ | 2-01¾ | 2-21¾ | 2-43 | 3-06 | 3-30¼ | 3-56¼ | 4-23½ | 4-52¼ |
| C.C.-0-30 | 0-02¼ | ...... | 0-04½ | 0-10¼ | 0-17¼ | 0-25¾ | 0-36 | 0-47½ | 1-00¾ | 1-15¼ | 1-31½ | 1-49 | 2-08¼ | 2-28¾ | 2-51 | 3-14½ | 3-39¾ | 4-06¼ | 4-34½ | 5-04 |
| C.C -0-45 | 0-07¾ | 0-04½ | ...... | 0-06¾ | 0-14½ | 0-24 | 0-34¾ | 0-47¼ | 1-01¼ | 1-16½ | 1-33½ | 1-51¾ | 2-11½ | 2-33 | 2-55¾ | 3-20¼ | 3-46 | 4-13½ | 4-42¼ | 5-12¾ |
| C.C.-1-00 | 0-16½ | 0-12½ | 0-06¾ | ...... | 0-09 | 0-19¼ | 0-30¾ | 0-43¾ | 0-58½ | 1-14¾ | 1-32¼ | 1-51½ | 2-12 | 2-34 | 2-57¾ | 3-22¾ | 3-49½ | 4-17½ | 4-47¼ | 5-18¼ |
| C.C.-1-15 | 0-28¼ | 0-23¼ | 0-16¾ | 0-09 | ...... | 0-11¼ | 0-23¾ | 0-37½ | 0-53 | 1-09¾ | 1-28 | 1-48 | 2-09½ | 2-32¼ | 2-56½ | 3-22½ | 3-49¾ | 4-18¾ | 4-49 | 5-21 |
| C.C.-1-30 | 0-42¾ | 0-37¼ | 0-30 | 0-21¼ | 0-11¼ | ...... | 0-13½ | 0-28¼ | 0-44¼ | 1-02 | 1-21 | 1-41½ | 2-03¾ | 2-27¼ | 2-52½ | 3-19 | 3-47¼ | 4-16¾ | 4-48 | 5-20½ |
| C.C.-1-45 | 1-00½ | 0-54 | 0-46 | 0-36¾ | 0-26 | 0-13½ | ...... | 0-15¾ | 0-32½ | 0-51 | 1-11 | 1-32¼ | 1-55 | 2-19½ | 2-45¼ | 3-12¾ | 3-41½ | 4-12 | 4-43¾ | 5-17¼ |
| C.C.-2-00 | 1-21 | 1-14 | 1-05¼ | 0-55¼ | 0-43½ | 0-30½ | 0-15¾ | ...... | 0-18 | 0-37¼ | 0-57¾ | 1-20 | 1-43½ | 2-08½ | 2-35¼ | 3-03¼ | 3-33 | 4-04 | 4-36¾ | 5-10¾ |
| C.C.-2-15 | 1-44½ | 1-36¾ | 1-27¼ | 1-16½ | 1-04 | 0-50¼ | 0-34¾ | 0-18 | ...... | 0-20¼ | 0-41½ | 1-04½ | 1-29 | 1-54¾ | 2-22 | 2-51 | 3-21¼ | 3-53¼ | 4-26½ | 5-01½ |
| C.C - 2-30 | 2-11¼ | 2-02¾ | 1-52½ | 1-41 | 1-27¾ | 1-13 | 0-57 | 0-39¼ | 0-20¼ | ...... | 0-22½ | 0-46¼ | 1-11¼ | 1-38 | 2-06 | 2-35½ | 3-06¾ | 3-39¼ | 4-13½ | 4-49 |
| C.C.-2-45 | 2-41 | 2-31½ | 2-20¾ | 2-08¼ | 1-54½ | 1-39 | 1-22 | 1-03¾ | 0-44 | 0-22½ | ...... | 0-24¾ | 0-50¾ | 1-18 | 1-46¾ | 2-17¼ | 2-49 | 3-22½ | 3-57¼ | 4-33¾ |
| C.C.-3-00 | 3-13½ | 3-03½ | 2-51¾ | 2-38½ | 2-24 | 2-08 | 1-50¼ | 1-31 | 1-10½ | 0-48¼ | 0-24¾ | ...... | 0-27 | 0-55 | 1-24¾ | 1-55¾ | 2-28½ | 3-02¾ | 3-38¼ | 4-15¼ |
| C.C -3-15 | 3-49¼ | 3-38¼ | 3-26 | 3-12 | 2-56½ | 2-39¾ | 2-21½ | 2-01½ | 1-40 | 1-17¼ | 0-52¾ | 0-27 | ...... | 0-29¼ | 0-59¾ | 1-31½ | 2-04¾ | 2-39¾ | 3-16 | 3-54 |
| C.C.-3-30 | 4-27¾ | 4-16¼ | 4-03 | 3-48½ | 3-32¼ | 3-14¾ | 2-55½ | 2-34¾ | 2-12¾ | 1-49¼ | 1-24 | 0-57½ | 0-29¼ | ...... | 0-31½ | 1-04 | 1-38¼ | 2-14 | 2;51 | 3-29½ |
| C.C.-3-45 | 5-09½ | 4-57 | 4-43¼ | 4-27¾ | 4-11 | 3-52½ | 3-32½ | 3-11¼ | 2-48½ | 2-24 | 1-58¼ | 1-30¾ | 1-01¾ | 0-31½ | ...... | 0-33¾ | 1-08½ | 1-45 | 2-22¾ | 3-02¼ |
| C.C.-4-00 | 5-54 | 5-41 | 5-26¼ | 5-10¼ | 4-52½ | 4-33½ | 4-12¾ | 3-50½ | 3-27 | 3-02 | 2-35¼ | 2-07¼ | 1-37½ | 1-06¼ | 0-33¾ | ...... | 0-36 | 1-13¼ | 1-51¾ | 2-32 |
| C.C.-4-15 | 6-41¾ | 6-27¾ | 6-12½ | 5-55½ | 5-37¼ | 5-17½ | 4-56 | 4-33 | 4-08¾ | 3-42¾ | 3-15½ | 2-46½ | 2-16 | 1-44¼ | 1-10¾ | 0-36 | ...... | 0-38¼ | 1-17½ | 1-58½ |
| C.C.-4-30 | 7-32¼ | 7-17¾ | 7-01½ | 6-44 | 6-24¾ | 6-04½ | 5-42 | 5-16½ | 4-53¼ | 4-26¾ | 3-58½ | 3-28¾ | 2-57¾ | 2-25 | 1-51 | 1-15¼ | 0-38¼ | ...... | 0-40½ | 1-22 |
| C.C.-4-45 | 8-26 | 8-10½ | 7-53¾ | 7-35¼ | 7-15½ | 6-54 | 6-31¼ | 6-06¾ | 5-41 | 5-13½ | 4-44¾ | 4-14¼ | 3-42½ | 3-09 | 2-34¼ | 1-57¾ | 1-20 | 0-40½ | ...... | 0-42¾ |
| C.C -5-00 | 9-22¾ | 9-06½ | 8-48¾ | 8-29¾ | 8-09 | 7-47 | 7-23¼ | 6-58¼ | 6-31½ | 6-03½ | 5-33¾ | 5-02¾ | 4-30 | 3-55¾ | 3-20¼ | 2-43 | 2-04½ | 1-24¼ | 0-42¾ | ...... |

| | | | | |
|---|---|---|---|---|
| C.C.- 5·00 | 566·59 | 40·25 | [illegible] | [illegible] |

## DIAGRAM
### Showing "D," "d," "t," of Tapering Curve Tables



Let I equal intersection angle of tangents to curve then:—

1– Distance from middle of curve to intersection point equals.

D× ex. sec. ½I+d, or $\frac{D}{\cos \frac{1}{2}I}$ – Radius of main [Curve]

2– Distance from B.C to intersection point equals D×tangent ½I+t.

3.. In running these curves on the ground it is best to fix the B.C. E.C. and C.C's of main curve from each other by the proper deflections and long chords, the other C.C's being put in by successive deflections and short chord measurements.

4. Should the main curve be other than one shown in the tables—for instance a 6°-30' curve, to be tapered per. Table 2—run in the tapering curve to C.C. 6°-00' (putting in this C.C. by tabular long chord and deflection), and then run in 15 feet of 6° to C.C. 6°-30'—in all cases taking some convenient length of chord for the last compounding of the tapering curve, which length shall have, as nearly as may be, the same relation to the tabular chord length as the main curve bears to the adjacent tabular curves. Get corrected values of D and t by multiplying cosine and sine of total curvature up to main curve by the difference of radii of main curve and of last branch of compound curve; subtract cosine product from D, and add sine product to t (as taken from the table for the last branch of the compound curve.)

FOR TABLE I

| Degree of Main Curve | "D." | "t." | Total Curvature in Tapering Curve at Each End of Main Curve. | "d" "D." less Radius of Main Curve. | Long Chord from B.C. of Taper to C.C. of Main Curve. |
|---|---|---|---|---|---|
| 1°-00' | 5729.61 | 15.01 | 0°-09' | 0.00 | 30.00 |
| 1-30 | 3819.80 | 30.00 | 0-27 | 0.06 | 60.00 |
| 2-00 | 2865.01 | 45.00 | 0-54 | 0.17 | 90.00 |
| 2-30 | 2292.24 | 60.00 | 1-30 | 0.37 | 120.00 |
| 3-00 | 1910.57 | 75.00 | 2-15 | 0.66 | 149.99 |
| 3-30 | 1638.17 | 89.99 | 3-09 | 1.08 | 179.98 |
| 4-00 | 1434.10 | 104.98 | 4-12 | 1.63 | 209.95 |
| 4-30 | 1275.66 | 119.96 | 5-24 | 2.34 | 239.91 |
| 5-00 | 1149.22 | 134.92 | 6-45 | 3.22 | 269.84 |
| 5-30 | 1046.14 | 149.87 | 8-15 | 4.30 | 299.73 |
| 6-00 | 960.63 | 164.79 | 9-54 | 5.59 | 329.57 |
| 6-30 | 888.71 | 179.69 | 11-42 | 7.11 | 359.35 |
| 7-00 | 827.53 | 194.54 | 13-39 | 8.89 | 389.03 |
| 7-30 | 775.02 | 209.35 | 15-45 | 10.94 | 418.61 |
| 8-00 | 729.62 | 224.10 | 18-00 | 13.28 | 448.05 |
| 8-30 | 690.14 | 238.78 | 20-24 | 15.92 | 477.33 |
| 9-00 | 655.66 | 253.38 | 22-57 | 18.88 | 506.41 |
| 9-30 | 625.47 | 267.88 | 25-39 | 22.18 | 535.25 |
| 10-00 | 598.97 | 282.27 | 28-30 | 25.83 | 563.82 |
| | | | | | |

| RADII FOR 50 FT. CHORDS | | | |
|---|---|---|---|
| Degree | Radius | Degree | Radius |
| 0°-30' | 11459.166 | 10°-30' | 545.865 |
| 1-00 | 5729.608 | 11-00 | 521.071 |
| 1-30 | 3819.742 | 11-30 | 498.433 |
| 2-00 | 2064.837 | 12-00 | 477.683 |
| 2-30 | 2291.876 | 12-30 | 458.594 |
| 3-00 | 1909.913 | 13-00 | 440.973 |
| 3-30 | 1637.086 | 13-30 | 424.659 |
| 4-00 | 1432.468 | 14-00 | 409.510 |
| 4-30 | 1273.321 | 14-30 | 395.407 |
| 5-00 | 1146.006 | 15-00 | 382.245 |
| 5-30 | 1041.841 | 15-30 | 369.932 |
| 6-00 | 955.041 | 16-00 | 358.390 |
| 6-30 | 681.592 | 16-30 | 347.547 |
| 7-00 | 818.639 | 17-00 | 337.343 |
| 7-30 | 764.080 | 17-30 | 327.723 |
| 8-00 | 716.343 | 18-00 | 318.637 |
| 8-30 | 674.222 | 18-30 | 310.043 |
| 9-00 | 636.784 | 19-00 | 301.902 |
| 9-30 | 603.286 | 19-30 | 294.179 |
| 10-00 | 573.139 | 20-00 | 286.843 |

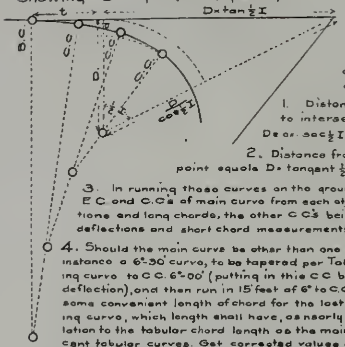
TABLE I — Tapering Curves Changing 0°-30' Each 30'

| TRANSIT AT | DEFLECTIONS TO | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B.C. 0°-30' | C.C. 1°-00' | C.C. 1°-30' | C.C. 2°-00' | C.C. 2°-30' | C.C. 3°-00' | C.C. 3°-30' | C.C. 4°-00' | C.C. 4°-30' | C.C. 5°-00' | C.C. 5°-30' | C.C. 6°-00' | C.C. 6°-30' | C.C. 7°-00 | C.C. 7°-30' | C.C. 8°-00 | C.C. 8°-30' | C.C. 9°-00 | C.C. 9°-30' | C.C. 10°-00' |
| B.C. 0°-30' | ........ | 0°-04½' | 0°-11¼' | 0°-21' | 0°-33¾' | 0°-49½' | 1°-08¼' | 1° 30' | 1°-54¾' | 2°-22½' | 2°-53¼' | 3°-27' | 4°-03¾' | 4°-43½' | 5°-26' | 6°-11¾' | 7°-00¼' | 7-52 | 8-46½ | 9-44 |
| C.C. 1-00 | 0-04½ | ------- | 0-09 | 0-20¼ | 0-34½ | 0-51¾ | 1-12 | 1-35¼ | 2-01½ | 2-30¾ | 3-03 | 3-38¼ | 4-16½ | 4-57¾ | 5-41¾ | 6-29 | 7-19¼ | 8-12¼ | 9-08¼ | 10-07¼ |
| C.C. 1-30 | 0-15¾ | 0-09 | ........ | 0-13½ | 0-29¼ | 0-48 | 1-09¾ | 1-34½ | 2-02¼ | 2-33 | 3-06¾ | 3-43½ | 4-23¼ | 5-06 | 5-51½ | 6-40¼ | 7-32 | 8-26½ | 9-24¼ | 10-24¾ |
| C.C. 2-00 | 0-33 | 0-24¾ | 0-13½ | ........ | 0-18 | 0-38¼ | 1-01½ | 1-27¾ | 1-57 | 2-29¼ | 3-04½ | 3-42¾ | 4-24 | 5-08¼ | 5-55½ | 6-45½ | 7-38¾ | 8-35 | 9-34 | 10-36 |
| C.C. 2-30 | 0-56¼ | 0-46½ | 0-33¾ | 0-18 | ....... | 0-22½ | 0-47¼ | 1-15 | 1-45¾ | 2-19½ | 2-56¼ | 3-36 | 4-18¾ | 5-04½ | 5-53¼ | 6-45 | 7-39½ | 8-37¼ | 9-37¾ | 10-41½ |
| C.C. 3-00 | 1-25½ | 1-14¼ | 1-00 | 0-42¾ | 0-22½ | ....... | 0-27 | 0-56¼ | 1-28½ | 2-03¾ | 2-42 | 3-23¼ | 4-07½ | 4-54¾ | 5-45 | 6-38¼ | 7-34¼ | 8-35½ | 9-35¾ | 10-40¾ |
| C.C. 3-30 | 2-00¾ | 1-48 | 1-32¼ | 0-13½ | 0-51¾ | 0-27 | ........ | 0-31½ | 1-05¼ | 1-42 | 2-21¾ | 3-04½ | 3-50¼ | 4-39 | 5-30¾ | 6-25½ | 7-23¼ | 8-23¾ | 9-27½ | 10-34 |
| C.C. 4-00 | 2-42 | 2-27¾ | 2-10½ | 1-50¼ | 1-27 | 1-00¾ | 0-31½ | ........ | 0-36 | 1-14¼ | 1-55½ | 2-39¾ | 3-27 | 4-17¼ | 5-10½ | 6-06¾ | 7-06 | 8-08 | 9-13¼ | 10-21½ |
| C.C. 4-30 | 3-29¼ | 3-13½ | 2-54¾ | 2-33 | 2-08¼ | 1-40½ | 1-09¾ | 0-36 | ........ | 0-40½ | 1-23¼ | 2-09 | 2-57¾ | 3-49½ | 4-44¼ | 5-42 | 6-42¾ | 7-46½ | 8-53 | 10-02¾ |
| C.C. 5-00 | .4-22½ | 4-05¼ | 3-45 | 3-21¾ | 2-55½ | 2-26¼ | 1-54 | 1-18¾ | 0-40½ | ........ | 0-45 | 1-32¼ | 2-22½ | 3-15¾ | 4-12 | 5-11¼ | 6-13½ | 7-18¾ | 8-27 | 9-38 |
| C.C. 5-30 | 5-21¾ | 5-03 | 4-41¼ | 4-16½ | 3-48¾ | 3-18 | 2-44¼ | 2-07½ | 1-27¾ | 0-45 | ........ | 0-49½ | 1-41¼ | 2-36 | 3-33¾ | 4-34½ | 5-38¼ | 6-45 | 7-54¾ | 9-07½ |
| C.C. 6-00 | 6-27 | 6-06¾ | 5-43½ | 5-17¼ | 4-48 | 4-15¾ | 3-40½ | 3-02¼ | 2-21 | 1-36¾ | 0-49½ | ........ | 0-54 | 1-50¼ | 2-49½ | 3-51¾ | 4-57 | 6-05¼ | 7-16½ | 8-30¾ |
| C.C. 6-30 | 7-38¼ | 7-16½ | 6-51¾ | 6-24 | 5-53¼ | 5-19½ | 4-42¾ | 4-03 | 3-20¼ | 2-34½ | 1-45¾ | 0-54 | ........ | 0-58½ | 1-59¼ | 3-03 | 4-09¾ | 5-19½ | 6-32¼ | 7-48 |
| C.C. 7-00 | 8-55½ | 8-32¼ | 8-06 | 7-36¾ | 7-04½ | 6-29¼ | 5-51 | 5-09¾ | 4-25½ | 3-38¼ | 2-48 | 1-54¾ | 0-58½ | ........ | 1-03 | 2-08¼ | 3-16½ | 4-27¾ | 5-42 | 6-55¼ |
| C.C. 7-30 | 10-19 | 9-54¼ | 9-26½ | 8-55½ | 8-21¾ | 7-45 | 7-05¼ | 6-22½ | 5-36¾ | 4-48 | 3-56¼ | 3-01½ | 2-03¾ | 1-03 | ........ | 1-07½ | 2-17¼ | 3-30 | 4-45¾ | 6-04½ |
| C.C. 8-00 | 11-46¼ | 11-22 | 10-52¾ | 10-20½ | 9-45 | 9-06¾ | 8-25½ | 7-41¼ | 6-54 | 6-03¾ | 5-10½ | 4-14¼ | 3-15 | 2-12¾ | 1-07½ | ........ | 1-12 | 2-26¼ | 3-43½ | 5-03¾ |
| C.C. 8-30 | 13-23¾ | 12-55¾ | 12-25 | 11-51¼ | 11-14½ | 10-34¾ | 9-51¾ | 9-06 | 8-17¼ | 7-25½ | 6-30¾ | 5-33 | 4-32¼ | 3-28½ | 2-21¾ | 1-12 | ........ | 1-16½ | 2-35¼ | 3-57 |
| C.C. 9-00 | 15-05 | 14-35¾ | 14-03½ | 13-28 | 12-49¾ | 12-08½ | 11-24¼ | 10-37 | 9-46½ | 8-53¼ | 7-57 | 6-57¾ | 5-55½ | 4-50¼ | 3-42 | 2-30¾ | 1-16½ | ........ | 1-21 | 2-44¼ |
| C.C. 9-30 | 16-52½ | 16-21¾ | 15-47¾ | 15-11 | 14-31¼ | 13-48¼ | 13-02½ | 12-13¾ | 11-22 | 10-27 | 6-29¼ | 8-28½ | 7-24¾ | 6-18 | 5-08¼ | 3-55½ | 2-39¾ | 1-21 | ........ | 1-25½ |
| C.C. 10-00 | 18-46 | 18-13¾ | 17-38¼ | 17-00 | 16-18½ | 15-34¼ | 14-47 | 13-56½ | 13-03¼ | 12-07 | 11-07½ | 10-05¼ | 9-00 | 7-51¾ | 6-40½ | 5-26¼ | 4-09 | 2-48¾ | 1-25½ | ....... |

| | | |
|---|---|---|
| cc.- 5.00 | 566.39 | 40.69 |

WESTERN SOCIETY OF ENGINEERS.
Vol. VII. No. 2.—PLATE IV.
Schenck—Transition Spirals.

## DIAGRAM
Showing "D" "d", "t." of Tapering Curve Tables.



Let I equal intersection angle of tangents to curve then:—

1. Distance from middle of curve to intersection point equals D = or. sec ½ I + d, or $\frac{D}{\cos \frac{1}{2} I}$ — Radius of main (Curve)

2. Distance from B.C. to intersection point equals D = tangent ½ I + t.

3. In running these curves on the ground it is best to fix the B.C. E.C. and C.C.'s of main curve from each other by the proper deflections and long chords, the other C.C.'s being put in by successive deflections and short chord measurements.

4. Should the main curve be other than one shown in the tables—for instance a 6°-30' curve, to be tapered per Table 2—run in the tapering curve to C.C. 6°-00' (putting in this C.C. by tabular long chord and deflection), and then run in 15 feet of 6° to C.C. 6°-30'—in all cases taking some convenient length of chord for the last compounding of the tapering curve, which length shall have, as nearly as may be, the same relation to the tabular chord length as the main curve bears to the adjacent tabular curves. Get corrected values of D and t by multiplying cosine and sine of total curvature up to main curve by the difference of radii of main curve and of last branch of compound curve; subtract cosine product from D, and add sine product to t (as taken from the table for the last branch of the compound curve)

## TABLE 2
### TAPERING CURVES Changing 1°-00' To Each 30 Ft.

| TRANSIT AT | DEFLECTIONS TO | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | B.C. 1° | C.C. 2° | C.C. 3° | C.C. 4° | C.C. 5° | C.C. 6° | C.C. 7° | C.C. 8° | C.C. 9° | C.C. 10° |
| | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' |
| B.C.-1° | ........ | 0-09 | 0-22½ | 0-42 | 1-07½ | 1-39 | 2-16½ | 3-00 | 3-49½ | 4-45 |
| C.C.-2° | 0-09 | ........ | 0-18 | 0-40½ | 1-09 | 1-43½ | 2-24 | 3-10½ | 4-03 | 5-01½ |
| C.C.-3° | 0-31½ | 0-18 | ........ | 0-27 | 0-58½ | 1-36 | 2-19½ | 3-09 | 4-04½ | 5-06 |
| C.C.-4° | 1-06 | 0-49½ | 0-27 | ........ | 0-36 | 1-16½ | 2-03 | 2-53½ | 3-54 | 4-58½ |
| C.C.-5° | 1-52½ | 1-33 | 1-07½ | 0-36 | ........ | 0-45 | 1-34½ | 2-30 | 3-31½ | 4-39 |
| C.C.-6° | 2-51 | 2-28½ | 2-00 | 1-25½ | 0-46 | ........ | 0-54 | 1-52½ | 2-37 | 4-07½ |
| C.C.-7° | 4-01½ | 3-36 | 3-04½ | 2-27 | 1-43½ | 0-54 | ........ | 1-03 | 2-10½ | 3-24 |
| C.C.-8° | 5-24 | 4-55½ | 4-21 | 3-40½ | 2-54 | 2-01½ | 1-03 | ........ | 1-12 | 2-26½ |
| C.C.-9° | 6-50½ | 6-27 | 5-49½ | 5-06 | 4-16½ | 3-21 | 2-13½ | 1-12 | ........ | 1-21 |
| C.C.-10° | 8-45 | 8-10½ | 7-30 | 6-43½ | 5-51 | 4-52½ | 3-40 | 2-37½ | 1-21 | ........ |

For Table 2.

| Degree of Main Curve. | "D." | "t." | Total Curvature in Tapering Curve at Each End of Main Curve | "d" = "D" less Radius of Main Curve | Long Chord from B.C. of Taper to C.C. of Main Curve |
|---|---|---|---|---|---|
| | | | ° ' | | |
| 2 | 2864.87 | 15.01 | 0-18 | 0.03 | 30 00 |
| 3 | 1910 06 | 30.01 | 0-54 | 0.14 | 60 00 |
| 4 | 1432 85 | 45.01 | 1-46 | 0 36 | 90 00 |
| 5 | 1146 78 | 60 00 | 3-00 | 0.77 | 119 99 |
| 6 | 956 40 | 74.99 | 4-30 | 1.30 | 149.96 |
| 7 | 820.82 | 89.93 | 6-18 | 2.18 | 179 91 |
| 8 | 719 62 | 104 90 | 8-24 | 3 28 | 209.81 |
| 9 | 641.47 | 119 80 | 10-48 | 4 69 | 239 69 |
| 10 | 579.53 | 134 86 | 13-30 | 6.45 | 269.36 |

## RADII FOR 50 FT. CHORDS

| Degree | Radius | Degree | Radius |
|---|---|---|---|
| ° '<br>1-00 | 3725 81 | ° '<br>6-00 | 955 04 |
| 1-30 | 3819.74 | 6-30 | 881 59 |
| 2-00 | 2864 84 | 7-00 | 810 64 |
| 2-30 | 2291.00 | 7-30 | 764 08 |
| 3-00 | 1909.91 | 8-00 | 716.34 |
| 3-30 | 1637.09 | 8-30 | 674 22 |
| 4-00 | 1432 47 | 9-00 | 636 78 |
| 4-30 | 1273 37 | 9-30 | 603 23 |
| 5-00 | 1146.01 | 10-00 | 573 14 |
| 5-30 | 1041.64 | | |

## TABLE 1
### TAPERING CURVES
Changing 0°-30' Each 30 Feet.

| TRANSIT AT | DEFLECTIONS TO | | | | | |
|---|---|---|---|---|---|---|
| | B.C. 0°-30' | C.C. 1°-00' | C.C. 1°-30' | C.C. 2°-00' | C.C. 2°-30' | C.C. 3°-00' |
| | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' |
| B.C.-0-30 | ........ | 0-04½ | 0-11¼ | 0-21 | 0-33¾ | 0-49½ |
| C.C.-1-00 | 0-04½ | ........ | 0-08 | 0-20¼ | 0-34½ | 0-51¾ |
| C.C.-1-30 | 0-13¾ | 0-08 | ........ | 0-18½ | 0-29¼ | 0-48 |
| C.C.-2-00 | 0-33 | 0-24¾ | 0-18½ | ........ | 0-18 | 0-38¼ |
| C.C.-2-30 | 0-36¼ | 0-44½ | 0-33¾ | 0-18 | ........ | 0-27½ |
| C.C.-3-00 | 1-25½ | 1-14¼ | 1-00 | 0-42¾ | 0-22½ | ........ |
| | | | | | | |
| | | | | | | |

For Table 1.

| Degree of Main Curve | "D." | "t." | Total Curvature in Tapering Curve at Each End of Main Curve. | "d" = "D" less Radius of Main Curve. | Long Chord from B.C. of Taper to C.C. of Main Curve. |
|---|---|---|---|---|---|
| 1°-00' | 5729 61 | 15 01 | ° '<br>0-09 | 0.00 | 30 00 |
| 1-30 | 3819 80 | 30 00 | 0-27 | 0.06 | 60 00 |
| 2-00 | 2865.01 | 45.00 | 0-54 | 0.17 | 90 00 |
| 2-30 | 2292 24 | 60 00 | 1-30 | 0 37 | 120 00 |
| 3-00 | 1910.57 | 75 00 | 2-15 | 0.66 | 149 99 |
| | | | | | |
| | | | | | |

## TABLE 3.
### TAPERING CURVES
Changing 2°-30' Each 30 Feet

| TRANSIT AT | DEFLECTIONS TO | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B.C. 2-30' | C.C. 5°-00' | C.C. 7°-30' | C.C. 10°-00' | C.C. 12°-30' | C.C. 15°-00' | C.C. 17°-30' | C.C. 20°-00 |
| | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' |
| B.C.-2-30 | ........ | 0-22½ | 0-56¼ | 1-45 | 2-46¾ | 4-07½ | 5-41 | 7-28½ |
| C.C.-5-00 | 0-22½ | ........ | 0-49 | 1-41¼ | 2-52½ | 4-10¾ | 6-00 | 7-36 |
| C.C.-7-30 | 1-16¾ | 0-45 | ........ | 1-07½ | 2-26¼ | 4-00 | 5-48¾ | 7-52½ |
| C.C.-10-00 | 2-45 | 2-08¾ | 1-07½ | ........ | 1-30 | 3-11¼ | 5-07½ | 7-10¾ |
| C.C.-12-30 | 4-41¼ | 3-32½ | 2-46¾ | 1-30 | ........ | 1-52½ | 3-56¼ | 6-15 |
| C.C.-15-00 | 7-07½ | 6-11¼ | 5-00 | 3-33¾ | 1-52½ | ........ | 2-15 | 4-41¼ |
| C.C.-17-30 | 10-04 | 9-00 | 7-41¼ | 6-07½ | 4-10¾ | 2-18 | ........ | 2-37½ |
| C.C.-20-00 | 13-30½ | 12-19 | 10-52½ | 9-11¼ | 7-15 | 5-03¾ | 2-37½ | ........ |

For Table 3.

| Degree of Main Curve. | "D." | "t." | Total Curvature in Tapering Curve at Each End of Main Curve. | "d" = "D" less Radius of Main Curve. | Long Chord from B.C. of Taper to C.C. of Main Curve. |
|---|---|---|---|---|---|
| ° '<br>5-00 | 1146.11 | 15 00 | ° '<br>0-45 | 0.10 | 30 00 |
| 7-30 | 764 48 | 29 90 | 2-18 | 0 40 | 60 00 |
| 10-00 | 574 12 | 44 97 | 4-30 | 0.99 | 89.98 |
| 12-30 | 460.56 | 59 93 | 7-30 | 1.97 | 119.92 |
| 15-00 | 385.68 | 74 82 | 11-15 | 3.43 | 149 76 |
| 17-30 | 333 20 | 89 62 | 15-45 | 5 48 | 179 43 |
| 20-00 | 295 04 | 104 27 | 21-00 | 8 20 | 208 60 |

## TABLE 4
### TAPERING CURVES
Changing 2°-30' Each 30 Feet.

| TRANSIT AT | DEFLECTIONS TO | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B.C. 2°-30' | C.C. 5°-00' | C.C. 7°-30' | C.C. 10°-00' | C.C. 12°-30' | C.C. 15°-00 | C.C. 17°-30' | C.C. 20°-00' |
| | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' | ° ' |
| B.C.-2-30 | ........ | 0-11¼ | 0-25⅝ | 0-32½ | 1-24⅜ | 2-08¾ | 2-50⅝ | 3-45 |
| C.C.-5-00 | 0-11¼ | ........ | 0-22½ | 0-50¾ | 1-26¼ | 2-09⅜ | 3-00 | 3-50⅝ |
| C.C.-7-30 | 0-28⅝ | 0-22½ | ........ | 0-33¾ | 1-18⅛ | 2-00 | 2-34⅜ | 3-56¼ |
| C.C.-10-00 | 1-22½ | 1-01⅞ | 0-33¾ | ........ | 0-45 | 1-56⅝ | 2-53¾ | 3-39⅜ |
| C.C.-12-30 | 2-20⅜ | 1-56¼ | 1-24⅜ | 0-45 | ........ | 0-56¼ | 1-50⅛ | 3-07½ |
| C.C.-16-00 | 3-33¾ | 3-04⅝ | 2-30 | 1-46⅞ | 0-36¼ | ........ | 1-07½ | 2-20⅝ |
| C.C.-17-30 | 3-01⅞ | 4-20 | 3-50⅜ | 3-03¾ | 2-05⅜ | 1-07½ | ........ | 1-18¾ |
| C.C.-20-00 | 6-45 | 6-09¾ | 3-28¼ | 4-35⅜ | 3-37½ | 2-31¾ | 1-16¾ | ........ |

For Table 4.

| Degree of Main Curve | "D." | "t." | Total Curvature in Tapering Curve at Each End of Main Curve. | "d" = "D" less Radius of Main Curve. | Long Chord from B.C. of Taper to C.C. of Main Curve |
|---|---|---|---|---|---|
| ° '<br>5-00 | 1146.03 | 7 50 | ° '<br>0-22½ | 0 02 | 15 00 |
| 7-30 | 764 16 | 15 00 | 1-07½ | 0.10 | 30 00 |
| 10-00 | 573 36 | 22 50 | 2-15 | 0 24 | 45 00 |
| 12-30 | 459.08 | 29 99 | 3-46 | 0.49 | 59 99 |
| 15-00 | 383.10 | 37 47 | 5-37½ | 0 86 | 74 97 |
| 17-30 | 329.09 | 44 94 | 7-52½ | 1.37 | 89 93 |
| 20-00 | 288 90 | 52 39 | 10-30 | 2 06 | 104 85 |

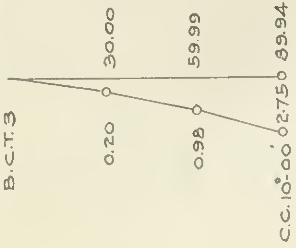
## TAPER CURVES

### LATITUDES & DEPARTURES FROM B.C's TO C.C's OF TAPERS

| TAPER ½ Changing 0°-15' -Each-30 feet. | | | TAPER 1. Changing 0°30' Each-30 feet. | | |
|---|---|---|---|---|---|
| STA. | LAT. | DEP'T | STA. | LAT. | DEP'T |
| B.C.-0°-15' | 0.00 | 0.00 | B.C.-0°-30' | 0.00 | 0.00 |
| C.C.-0-30 | 30.00 | 0.02 | C.C.-1-00 | 30.00 | 0.04 |
| C.C.-0-45 | 60.00 | 0.10 | C.C.-1-30 | 60.00 | 0.20 |
| C.C.-1-00 | 90.00 | 0.27 | C.C.-2-00 | 90.00 | 0.55 |
| C.C.-1-15 | 120.00 | 0.59 | C.C.-2-30 | 119.99 | 1.18 |
| C.C.-1-30 | 149.99 | 1.08 | C.C.-3-00 | 149.97 | 2.16 |
| C.C.-1-45 | 179.99 | 1.79 | C.C.-3-30 | 179.94 | 3.57 |
| C.C.-2-00 | 209.97 | 2.75 | C.C.-4-00 | 209.88 | 5.50 |
| C.C.-2-15 | 239.94 | 4.00 | C.C.-4-30 | 239.77 | 8.01 |
| C.C.-2-30 | 269.90 | 5.59 | C.C.-5-00 | 269.61 | 11.18 |
| C.C.-2-45 | 299.84 | 7.56 | C.C.-5-30 | 299.35 | 15.10 |
| C.C.-3-00 | 329.74 | 9.93 | C.C.-6-00 | 328.97 | 19.83 |
| C.C.-3-15 | 359.61 | 12.75 | C.C.-6-30 | 358.44 | 25.45 |
| C.C.-3-30 | 389.43 | 16.06 | C.C.-7-00 | 387.71 | 32.03 |
| C.C.-3-45 | 419.18 | 19.90 | C.C.-7-30 | 416.73 | 39.65 |
| C.C.-4-00 | 448.86 | 24.30 | C.C.-8-00 | 445.44 | 48.35 |
| C.C.-4-15 | 478.44 | 29.31 | C.C.-8-30 | 473.77 | 58.22 |
| C.C.-4-30 | 507.90 | 34.95 | C.C.-9-00 | 501.65 | 69.30 |
| C.C.-4-45 | 537.23 | 41.26 | C.C.-9-30 | 528.99 | 81.65 |
| C.C.-5-00 | 566.39 | 48.29 | C.C.-10-00 | 555.70 | 95.30 |

| TAPER 2. Changing 1°-00' Each-30 feet | | | TAPER 3. Changing 2°-30' Each-30 feet | | |
|---|---|---|---|---|---|
| STA. | LAT. | DEP'T | STA. | LAT. | DEP'T |
| B.C-1°-00' | 0.00 | 0.00 | B.C.-2-30' | 0.00 | 0.00 |
| C.C.-2-00 | 30.00 | 0.08 | C.C.-5-00 | 30.00 | 0.20 |
| C.C.-3-00 | 60.00 | 0.39 | C.C.-7-30 | 59.99 | 0.98 |
| C.C.-4-00 | 89.99 | 1.10 | C.C.-10-00 | 89.94 | 2.75 |
| C.C.-5-00 | 119.96 | 2.36 | C.C.-12-30 | 119.77 | 5.88 |
| C.C.-6-00 | 149.90 | 4.32 | C.C.-15-00 | 149.37 | 10.77 |
| C.C.-7-00 | 179.77 | 7.14 | C.C.-17-30 | 179.54 | 17.77 |
| C.C.-8-00 | 209.52 | 10.98 | C.C.-20-00 | 207.01 | 27.23 |
| C.C.-9-00 | 239.10 | 15.98 | | | |
| C.C.-10-00 | 268.43 | 22.30 | | | |

| TAPER 4 Changing 2°-30' Each 15 ft. | | |
|---|---|---|
| B.C.-2-30 | 0.00 | 0.00 |
| C.C.-5-00 | 15.00 | 0.05 |
| C.C.-7-30 | 30.00 | 0.25 |
| C.C.-10-00 | 44.99 | 0.69 |
| C.C.-12-30 | 59.97 | 1.47 |
| C.C.-15-00 | 74.92 | 2.70 |
| C.C.-17-30 | 89.82 | 4.46 |
| C.C.-20-00 | 104.63 | 6.86 |



| GRADE $0\frac{7}{10}$ FT. PER 100 MAX. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tapers on $0\frac{7}{10}$ Max. Grade | | | | | | Curves on $0\frac{7}{10}$ Ft. Max. Grade | | |
| TAPER 1. | | | TAPER 2 | | | | | |
| Main Curve | Rate | Change in feet. | Main Curve | Rate | Change in feet. | Main Curve | Rate per degree per sta 100 ft. | Rate per. 100. |
| 1°-00′ | 0.68 | 0.204 | 2°-00′ | 0.66 | 0.198 | 0°-30′ | 0.040 | 0.68 |
| 1-30 | 0.67 | 0.402 | 3-00 | 0.64 | 0.384 | 1°-00 | | 0.66 |
| 2-00 | 0.66 | 0.594 | 4-00 | 0.61 | 0.549 | 1-30 | | 0.64 |
| 2-30 | 0.65 | 0.780 | 5-00 | 0.5875 | 0.705 | 2-00 | | 0.62 |
| 3-00 | 0.64 | 0.960 | 6-00 | 0.565 | 0.848 | 2-30 | | 0.60 |
| 3-30 | 0.62125 | 1.118 | 7-00 | 0.525 | 0.945 | 3-00 | 0.040 | 0.58 |
| 4-00 | 0.61 | 1.281 | 8-00 | 0.50 | 1.050 | 3-30 | 0.045 | 0.5425 |
| 4-30 | 0.59875 | 1.437 | 9-00 | 0.4525 | 1.086 | 4-00 | | 0.52 |
| 5-00 | 0.5875 | 1.586 | 10-00 | 0.425 | 1.148 | 4-30 | | 0.4975 |
| 5-30 | 0.57625 | 1.729 | TAPER 3. | | | 5-00 | | 0.475 |
| 6-00 | 0.565 | 1.865 | | | | 5-30 | | 0.4525 |
| 6-30 | 0.5375 | 1.935 | 5-00 | 0.5875 | 0.176 | 6-00 | 0.045 | 0.43 |
| 7-00 | 0.525 | 2.048 | 7-30 | 0.5125 | 0.303 | 6-30 | 0.050 | 0.375 |
| 7-30 | 0.5125 | 2.153 | 10-00 | 0.425 | 0.383 | 7-00 | | 0.35 |
| 8-00 | 0.50 | 2.250 | TAPER 4. | | | 7-30 | | 0.325 |
| 8-30 | 0.4875 | 2.340 | | | | 8-00 | | 0.300 |
| 9-00 | 0.4525 | 2.308 | 5-00 | 0.5875 | 0.881 | 8-30 | 0.050 | 0.275 |
| 9-30 | 0.43875 | 2.369 | 7-30 | 0.5125 | 0.154 | 9-00 | 0.055 | 0.205 |
| 10-00 | 0.425 | 2.423 | 10-00 | 0.425 | 0.191 | 9-30 | | 0.1775 |
| | | | | | | 10-00 | 0.055 | 0.15 |

Note – This is same as Belgian Formula. Our Operating Experience proves it to be much more compensation than necessary. W. H.

| GRADE 1 FOOT PER. 100 FEET MAX. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CURVES ON 1 FOOT MAX. GRADE | | | TAPERS ON 1 FOOT MAX. GRADE | | | | | |
| | | | TAPER 1 | | | TAPER 3 | | |
| Main Curve | Rate per degree per sta 100 ft | Rate per 100 | Main Curve | Rate | Change | Main Curve | Rate | Change |
| 0°-30' | 0 035 | 0 9825 | 1°-00' | 0.9825 | 0.295 | 5°-00' | 0.900 | 0 27 |
| 1-00 | | 0.965 | 1-30 | 0 97375 | 0.584 | 7-30 | 0.83125 | 0.499 |
| 1-30 | | 0 9475 | 2-00 | 0 965 | 0.868 | 10-00 | 0.750 | 0.675 |
| 2-00 | | 0.93 | 2-30 | 0 95625 | 1.148 | TAPER 4 | | |
| 2-30 | | 0.9125 | 3-00 | 0.9475 | 1.421 | | | |
| 3-00 | 0 035 | 0.895 | TAPER 2. | | | 5-00 | 0.90 | 0.135 |
| 3-30 | 0.040 | 0.86 | | | | 7-30 | 0.83125 | 0.249 |
| 4-00 | | 0.84 | 2-00 | 0.965 | 0.290 | 10-00 | 0 750 | 0 338 |
| 4-30 | | 0.82 | 3-00 | 0.9475 | 0.5685 | | | |
| 5-00 | | 0.80 | 4-00 | 0.920 | 0.828 | | | |
| 5-30 | | 0 78 | 5-00 | 0 900 | 1.080 | | | |
| 6-00 | 0 040 | 0 76 | 6-00 | 0.880 | 1.320 | | | |
| 6-30 | 0 045 | 0 7075 | 7-00 | 0.8425 | 1.517 | | | |
| 7-00 | | 0 685 | 8-00 | 0.820 | 1.722 | | | |
| 7-30 | | 0 6625 | 9-00 | 0 775 | 1.860 | | | |
| 8-00 | | 0.640 | 10-00 | 0 75 | 2 025 | | | |
| 8-30 | 0 045 | 0 6175 | | | | | | |
| 9-00 | 0 050 | 0 55 | | | | | | |
| 9-30 | | 0 525 | | | | | | |
| 10-00 | 0.050 | 0.500 | | | | | | |

Note

The rule is that the whole taper will be on one grade rate from B.C to B.C. or (B.B.) of main curve and the entire rise or fall in taper is equal to the Max Grade. for that distance, less the compensation due to the Curvature in the taper compensated at same rate as in main curve. For instance a 10°, taper 1, has a length of 570 feet and a curvature of 28°-30' Change = 5.700 less 1425 = 4.275 feet, total change or Rate is $\frac{4\,275}{5.70} = 0.\frac{75}{100}$ per. station grade rate.

## MAXIMUM GRADE 1 FOOT PER. 100 (ON TANGENT

| Taper on 1 foot % Max Grade | | | | | | Main Curve on 1 foot % Max. | | | Taper on 1 foot % Max Grade | | | | | | Main Curve on 1 foot % Max. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Curve | Rate on Tapers | Taper ½ | Taper 1 | Taper 2 | Taper 3 | Main Curve | Rate per degree per 100 ft. Sta. | Rate per 100 ft. | Main Curve | Rate on Tapers | Taper ½ | Taper 1 | Taper 2 | Taper 3 | Main Curve | Rate per degree per 100 ft. Sta. | Rate per 100 ft. |
| | | Change in feet | Change in feet | Change in feet | Change in feet | | | | | | Change in feet | Change in feet | Change in feet | Change in feet | | | |
| ° ′ | | | | | | ° ′<br>0-15 | 0.035 | 0.99125 | ° ′<br>4-15 | 0.915 | 4.392 | | | | ° ′<br>4-15 | | 0.83 |
| 0-30 | 0.99125 | 0.297 | | | | 0-30 | | 0.9825 | 4-30 | 0.91 | 4.641 | 2.184 | | | 4-30 | | 0.82 |
| 0-45 | 0.986875 | 0.592 | | | | 0-45 | | 0.97375 | 4-45 | 0.905 | 4.887 | | | | 4-45 | | 0.81 |
| 1-00 | 0.9825 | 0.884 | 0.295 | | | 1-00 | | 0.965 | 5-00 | 0.9 | 5.130 | 2.430 | 1.080 | 0.270 | 5-00 | | 0.80 |
| 1-15 | 0.978125 | 1.174 | | | | 1-15 | | 0.95625 | 5-30 | 0.89 | | 2.670 | | | 5-30 | | 0.78 |
| 1-30 | 0.97375 | 1.461 | 0.584 | | | 1-30 | | 0.9475 | 6-00 | 0.88 | | 2.904 | 1.320 | | 6-00 | 0.040 | 0.76 |
| 1-45 | 0.969375 | 1.745 | | | | 1-45 | | 0.93875 | 6-30 | 0.85375 | | 3.074 | | | 6-30 | 0.045 | 0.7075 |
| 2-00 | 0.965 | 2.027 | 0.868 | 0.290 | | 2-00 | | 0.93 | 7-00 | 0.8425 | | 3.286 | 1.517 | | 7-00 | | 0.685 |
| 2-15 | 0.960625 | 2.306 | | | | 2-15 | | 0.92125 | 7-30 | 0.83125 | | 3.491 | | 0499 | 7-30 | | 0.6625 |
| 2-30 | 0.95625 | 2.582 | 1.148 | | | 2-30 | | 0.9125 | 8-00 | 0.82 | | 3.690 | 1.722 | | 8-00 | | 0.64 |
| 2-45 | 0.951875 | 2.856 | | | | 2-45 | | 0.90375 | 8-30 | 0.80875 | | 3.882 | | | 8-30 | 0.045 | 0.6175 |
| 3-00 | 0.9475 | 3.127 | 1.421 | 0.569 | | 3-00 | 0.035 | 0.895 | 9-00 | 0.775 | | 3.953 | 1.860 | | 9-00 | 0.050 | 0.55 |
| 3-15 | 0.935 | 3.366 | | | | 3-15 | 0.040 | 0.87 | 9-30 | 0.7625 | | 4.118 | | | 9-30 | | 0.525 |
| 3-30 | 0.93 | 3.627 | 1.674 | | | 3-30 | | 0.86 | 10-00 | 0.75 | | 4.275 | 2.025 | 0.675 | 10-00 | 0.050 | 0.5 |
| 3-45 | 0.925 | 3.885 | | | | 3-45 | | 0.85 | | | | | | | | | |
| 4-00 | 0.92 | 4.140 | 1.932 | 0.828 | | 4-00 | | 0.84 | | | | | | | | | |

Note

The maximum grade rate on tapers is the mean of the maximum grade on tangent and the maximum grade on the main curve to which the taper curve belongs.

MAXIMUM GRADE $1\frac{25}{100}$ FT. PER. 100 (ON TANGENT)

| Tapers on $1\frac{25}{100}$ ft. % Max Grade | | | | | | Main Curve on $1\frac{25}{100}$ ft. % Max. | | | Tapers on $1\frac{25}{100}$ ft. % Max. Grade | | | | | | Main Curve on $1\frac{25}{100}$ ft. % Max. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Curve | Rate on Tapers | CHANGE IN FEET Taper $\frac{1}{2}$. | Taper 1. | Taper 2. | Taper 3. | Main Curve | Rate per degree per 100 ft. Sta. | Rate per 100 ft. | Main Curve | Rate on Tapers | CHANGE IN FEET Taper $\frac{1}{2}$. | Taper 1. | Taper 2. | Taper 3. | Main Curve | Rate per degree per 100 ft. Sta. | Rate per 100 ft. |
| ° ′ | | | | | | ° ′<br>0-15 | 0.035 | 1.24125 | ° ′<br>4-15 | 1.165 | 5.592 | | | | ° ′<br>4-15 | | 1.08 |
| 0-30 | 1.24125 | 0.372 | | | | 0-30 | | 1.2325 | 4-30 | 1.16 | 5.916 | 2.784 | | | 4-30 | | 1.07 |
| 0-45 | 1.236875 | 0.742 | | | | 0-45 | | 1.22375 | 4-45 | 1.155 | 6.237 | | | | 4-45 | | 1.06 |
| 1-00 | 1.2325 | 1.109 | 0.370 | | | 1-00 | | 1.215 | 5-00 | 1.15 | 6.555 | 3.105 | 1.380 | 0.345 | 5-00 | | 1.05 |
| 1-15 | 1.228125 | 1.474 | | | | 1-15 | | 1.20625 | 5-30 | 1.14 | | 3.420 | | | 5-30 | | 1.03 |
| 1-30 | 1.22375 | 1.836 | 0.734 | | | 1-30 | | 1.1975 | 6-00 | 1.13 | | 3729 | 1.695 | | 6-00 | 0.040 | 1.01 |
| 1-45 | 1.219375 | 2.195 | | | | 1-45 | | 1.18875 | 6-30 | 1.10375 | | 3.974 | | | 6-30 | 0.045 | 0.9575 |
| 2-00 | 1.215 | 2.552 | 1.094 | 0365 | | 2-00 | | 1.18 | 7-00 | 1.0925 | | 4.261 | 1.967 | | 7-00 | | 0.935 |
| 2-15 | 1.210625 | 2.906 | | | | 2-15 | | 1.17125 | 7-30 | 1.08125 | | 4.541 | | 0.649 | 7-30 | | 0.9125 |
| 2-30 | 1.20625 | 3257 | 1.448 | | | 2-30 | | 1.1625 | 8-00 | 1.07 | | 4.815 | 2.247 | | 8-00 | | 0.89 |
| 2-45 | 1201875 | 3.606 | | | | 2-45 | | 1.15375 | 8-30 | 1.05875 | | 5.082 | | | 8-30 | 0.045 | 0.8675 |
| 3-00 | 1.1975 | 3.952 | 1.796 | 0.719 | | 3-00 | 0.035 | 1.145 | 9-00 | 1.025 | | 5.228 | 2.460 | | 9-00 | 0.050 | 0.80 |
| 3-15 | 1185 | 4.266 | | | | 3-15 | 0.040 | 1.12 | 9-30 | 1.0125 | | 5.468 | | | 9-30 | | 0.775 |
| 3-30 | 1.18 | 4 602 | 2.124 | | | 3-30 | | 1.11 | 10-00 | 1.00 | | 5.7 | 2700 | 0.900 | 10-00 | 0 050 | 0.75 |
| 3-45 | 1175 | 4.935 | | | | 3-45 | | 1.10 | | | | | | | | | |
| 4-00 | 1.17 | 5265 | 2.457 | 1.053 | | 4-00 | | 1.09 | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

Note

The maximum grade rate on tapers is the mean of the maximum grade on tangent and the maximum grade on the main curve to which the taper curve belongs.

MAXIMUM GRADE $1\frac{5}{10}$ FT. PER. 100 (ON TANGENT)

| Tapers on $1\frac{5}{10}$ ft. % Max Grade. | | | | | | Main Curve on $1\frac{5}{10}$ ft. % Max. | | | Tapers on $1\frac{5}{10}$ ft. % Max. Grade | | | | | | Main Curve on $1\frac{5}{10}$ ft. % Max. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Curve | Rate on Tapers | CHANGE IN FEET | | | | Main Curve | Rate per degree per 100 ft. Sta. | Rate per 100 ft. | Main Curve | Rate on Tapers | CHANGE IN FEET | | | | Main Curve | Rate per degree per 100 ft. Sta. | Rate per 100 ft. |
| | | Taper ½. | Taper 1. | Taper 2. | Taper 3. | | | | | | Taper ½. | Taper 1. | Taper 2. | Taper 3. | | | |
| ° ′ | | | | | | ° ′ 0-15 | 0.035 | 1.49125 | ° ′ 4-15 | 1.415 | 6.792 | | | | ° ′ 4-15 | | 1.33 |
| 0-30 | 1.49125 | 0.447 | | | | 0-30 | | 1.4825 | 4-30 | 1.41 | 7.191 | 3.384 | | | 4-30 | | 1.32 |
| 0-45 | 1.486875 | 0.892 | | | | 0-45 | | 1.47375 | 4-45 | 1.405 | 7.587 | | | | 4-45 | | 1.31 |
| 1-00 | 1.4825 | 1.334 | 0.445 | | | 1-00 | | 1.465 | 5-00 | 1.40 | 7.980 | 3.780 | 1.680 | 0.420 | 5-00 | | 1.30 |
| 1-15 | 1.478125 | 1.774 | | | | 1-15 | | 1.45625 | 5-30 | 1.39 | | 4.170 | | | 5-30 | | 1.28 |
| 1-30 | 1.47375 | 2.211 | 0.884 | | | 1-30 | | 1.4475 | 6-00 | 1.38 | | 4.554 | 2.070 | | 6-00 | 0.040 | 1.26 |
| 1-45 | 1.469375 | 2.645 | | | | 1-45 | | 1.43875 | 6-30 | 1.35375 | | 4.874 | | | 6-30 | 0.045 | 1.2075 |
| 2-00 | 1.465 | 3.077 | 1.319 | 0.440 | | 2-00 | | 1.43 | 7-00 | 1.3425 | | 5.236 | 2.417 | | 7-00 | | 1.185 |
| 2-15 | 1.460625 | 3.506 | | | | 2-15 | | 1.42125 | 7-30 | 1.33125 | | 5.591 | | 0.799 | 7-30 | | 1.1625 |
| 2-30 | 1.45625 | 3.932 | 1.748 | | | 2-30 | | 1.4125 | 8-00 | 1.32 | | 5.940 | 2.772 | | 8-00 | | 1.14 |
| 2-45 | 1.451875 | 4.356 | | | | 2-45 | | 1.40375 | 8-30 | 1.30875 | | 6.282 | | | 8-30 | 0.045 | 1.1175 |
| 3-00 | 1.4475 | 4.777 | 2.171 | 0.869 | | 3-00 | 0.035 | 1.395 | 9-00 | 1.275 | | 6.503 | 3.060 | | 9-00 | 0.050 | 1.050 |
| 3-15 | 1.435 | 5.166 | | | | 3-15 | 0.040 | 1.37 | 9-30 | 1.2625 | | 6.818 | | | 9-30 | | 1.025 |
| 3-30 | 1.43 | 5.577 | 2.574 | | | 3-30 | | 1.36 | 10-00 | 1.25 | | 7.125 | 3.375 | 1.125 | 10-00 | 0.050 | 1.000 |
| 3-45 | 1.425 | 5985 | | | | 3-45 | | 1.35 | | | | | | | | | |
| 4-00 | 1.42 | 6.390 | 2.982 | 1.278 | | 4-00 | | 1.34 | | | | | | | | | |

Note

The maximum grade rate on tapers is the mean of the maximum grade on tangent and the maximum grade on the main curve to which the taper curve belongs.

| MAXIMUM GRADE $2\frac{2}{10}$ FT. PER 100 (ON TANGENT) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tapers on $2\frac{2}{10}$ ft. % Max Grade | | | | | | Main Curve on $2\frac{2}{10}$ ft. % Max. | | | Tapers on $2\frac{2}{10}$ ft % Max Grade | | | | | | Main Curve on $2\frac{2}{10}$ ft. % Max. | | |
| Main Curve | Rate on Tapers | CHANGE IN FEET | | | | Main Curve | Rate per degree per 100 ft Sta. | Rate per 100 ft. | Main Curve | Rate on Tapers | CHANGE IN FEET | | | | Main Curve | Rate per degree per 100 ft Sta. | Rate per 100 ft. |
| | | Taper $\frac{1}{2}$ | Taper 1. | Taper 2. | Taper 3 | | | | | | Taper $\frac{1}{2}$. | Taper 1. | Taper 2. | Taper 3 | | | |
| ° ′ | | | | | | ° 0-15 | 0.035 | 2.19125 | ° ′ 4-15 | 2.115 | 10.152 | | | | ° ′ 4-15 | | 2.03 |
| 0-30 | 2.19125 | 0.657 | | | | 0-30 | | 2.1825 | 4-30 | 2.11 | 10.761 | 5.064 | | | 4-30 | | 2.02 |
| 0-45 | 2.186875 | 1.312 | | | | 0-45 | | 2.17375 | 4-45 | 2.105 | 11.367 | | | | 4-45 | | 2.01 |
| 1-00 | 2.1825 | 1.964 | 0.655 | | | 1-00 | | 2.165 | 5-00 | 2.10 | 11.970 | 5.670 | 2.520 | 0.630 | 5-00 | | 2.00 |
| 1-15 | 2.178125 | 2.614 | | | | 1-15 | | 2.15625 | 5-30 | 2.09 | | 6.270 | | | 5-30 | | 1.98 |
| 1-30 | 2.17375 | 3.261 | 1.304 | | | 1-30 | | 2.1475 | 6-00 | 2.08 | | 6.864 | 3.120 | | 6-00 | 0.040 | 1.96 |
| 1-45 | 2.169375 | 3.905 | | | | 1-45 | | 2.13875 | 6-30 | 2.05375 | | 7.394 | | | 6-30 | 0.045 | 1.9075 |
| 2-00 | 2.165 | 4.547 | 1.949 | 0.650 | | 2-00 | | 2.13 | 7-00 | 2.0425 | | 7.966 | 3.677 | | 7-00 | | 1.885 |
| 2-15 | 2.160625 | 5.186 | | | | 2-15 | | 2.12125 | 7-30 | 2.03125 | | 8.531 | | 1.219 | 7-30 | | 1.8625 |
| 2-30 | 2.15625 | 5.822 | 2.588 | | | 2-30 | | 2.1125 | 8-00 | 2.02 | | 9.090 | 4.242 | | 8-00 | | 1.84 |
| 2-45 | 2.151875 | 6.456 | | | | 2-45 | | 2.10375 | 8-30 | 2.00875 | | 9.642 | | | 8-30 | 0.045 | 1.8175 |
| 3-00 | 2.1475 | 7.087 | 3.221 | 1.289 | | 3-00 | 0.035 | 2.095 | 9-00 | 1.975 | | 10.073 | 4.740 | | 9-00 | 0.050 | 1.750 |
| 3-15 | 2.135 | 7.686 | | | | 3-15 | 0.040 | 2.07 | 9-30 | 1.9625 | | 10.598 | | | 9-30 | | 1.725 |
| 3-30 | 2.13 | 8.307 | 3.834 | | | 3-30 | | 2.06 | 10-00 | 1.95 | | 11.115 | 5.265 | 1.755 | 10-00 | 0.050 | 1.700 |
| 3-45 | 2.125 | 8.925 | | | | 3-45 | | 2.05 | | | | | | | | | |
| 4-00 | 2.12 | 9.540 | 4.452 | 1.908 | | 4-00 | | 2.04 | | | | | | | | | |

Note

The maximum grade rate on tapers is the mean of the maximum grade on tangent and the maximum grade on the main curve to which the taper curve belongs.

*Mr. George H. Bremner*—The paper we have heard to-night from Mr. Torrance is a valuable contribution on the subject of transition curves, and I do not desire to take issue with him on any of the points he has raised.

I would like, however, to present to the Society a set of tables which are prepared in somewhat different shape from his, and from

SPEED OF TRAINS FOR DIFFERENT RATES OF RAISE OF OUTER RAIL ON TRANSITION CURVES.

| LENGTH PER DEGREE OF CUR. | RAISE 1/4" IN 30' |  |  | RAISE 3/8" IN 30' |  |  | RAISE 1/2" IN 30' |  |  | RAISE 3/4" IN 30' |  |  | RAISE 1" IN 30' |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | ELEVATION OF OUTER RAIL PER DEGREE OF CURVE |  | SPEED IN MI. PER HOUR | ELEVATION OF OUTER RAIL PER DEGREE OF CURVE |  | SPEED IN MI. PER HOUR | ELEVATION OF OUTER RAIL PER DEGREE OF CURVE |  | SPEED IN MI. PER HOUR | ELEVATION OF OUTER RAIL PER DEGREE OF CURVE |  | SPEED IN MI. PER HOUR | ELEVATION OF OUTER RAIL PER DEGREE OF CURVE |  | SPEED IN MI. PER HOUR |
|  | FT. | IN. |  | FT. | IN. |  | FT. | IN. |  | FT. | IN. |  | FT. | IN. |  |
| 20 | .0139 | 5/32 | 16 | .0208 | 1/4 | 19 | .0278 | 11/32 | 23 | .0417 | 1/2 | 28 | .0556 | 21/32 | 31 |
| 25 | .0173 | 7/32 | 18 | .0260 | 5/16 | 22 | .0347 | 13/32 | 25 | .0520 | 5/8 | 30 | .0693 | 27/32 | 35 |
| 30 | .0208 | 1/4 | 19 | .0312 | 3/8 | 24 | .0417 | 1/2 | 28 | .0624 | 3/4 | 33 | .0833 | 1 | 39 |
| 40 | .0278 | 11/32 | 23 | .0417 | 1/2 | 28 | .0556 | 21/32 | 31 | .0833 | 1 | 39 | .1111 | 1 11/32 | 45 |
| 50 | .0347 | 13/32 | 25 | .0520 | 5/8 | 30 | .0694 | 27/32 | 35 | .1040 | 1 1/4 | 44 | .1388 | 1 21/32 | 50 |
| 75 | .0520 | 5/8 | 30 | .0780 | 15/16 | 37 | .1040 | 1 1/4 | 44 | .1560 | 1 7/8 | 53 | .2080 | 2 1/2 | 61 |
| 100 | .0693 | 27/32 | 35 | .1040 | 1 1/4 | 44 | .1387 | 1 21/32 | 50 | .2080 | 2 1/2 | 62 | .2774 | 3 5/16 | 70 |
| 125 | .0867 | 1 1/32 | 40 | .1300 | 1 9/16 | 49 | .1733 | 2 1/16 | 56 | .2600 | 3 1/8 | 70 | .3466 | 4 1/8 | 78 |
| 150 | .1040 | 1 1/4 | 44 | .1560 | 1 7/8 | 53 | .2080 | 2 1/2 | 61 | .3120 | 3 3/4 | 75 | .4160 | 5 | 86 |
| 175 | .1213 | 1 15/32 | 47 | .1820 | 2 3/16 | 58 | .2427 | 2 29/32 | 66 | .3640 | 4 3/8 | 80 | .4864 | 5 13/16 | 94 |
| 200 | .1387 | 1 21/32 | 50 | .2080 | 2 1/2 | 62 | .2773 | 3 5/16 | 70 | .4160 | 5 | 86 | .5546 | 6 21/32 | 101 |

most of those now in print, and which are convenient for use in relining old track under the usual conditions in the prairie states.

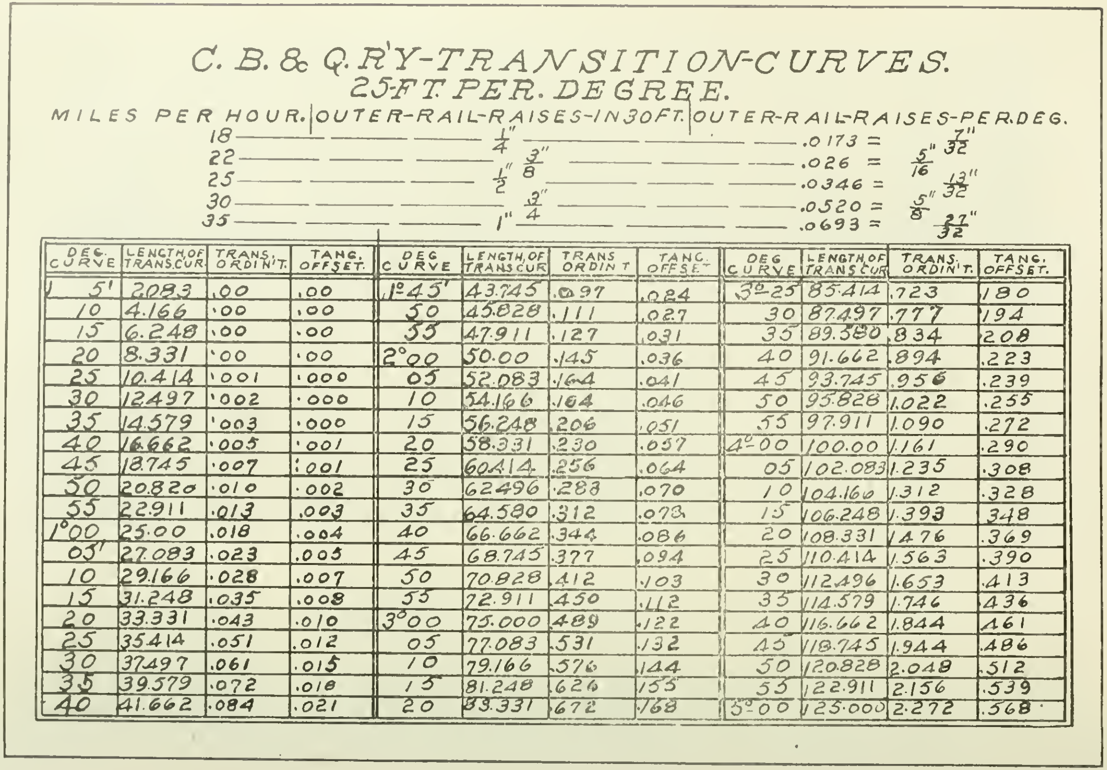
The usual tables do not give long enough transition curves for high speed, and are not elastic enough. For sharp curves such as are used in street railway construction, and also for such as are

## C. B. & Q. RY-TRANSITION-CURVES.
## 20-FT PER. DEGREE.

MILES PER HOUR. OUTER-RAIL-RAISES-IN 30 FT. OUTER-RAIL-RAISES-PER DEG.
16 ——— 1/4" ——— .0139 = 5/32"
19 ——— 3/8" ——— .0208 = 1/4"
23 ——— 1/2" ——— .0278 = " 11/32"
28 ——— 3/4 ——— .0417 = 1/2
31 ——— 1" ——— .0556 = 21/32"

| DEG. CURVE | LENGTH OF TRANS. CUR | TRANS. ORDIN'T | TANG. OFFSET. | DEG. CURVE | LENGTH OF TRANS. CUR | TRANS. ORDIN'T | TANG. OFFSET | DEG. CURVE | LENGTH OF TRANS. CUR | TRANS. ORDIN'T. | TANG. OFFSET. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00° 5 | 1.67 | .000 | .000 | 1°-45 | 35.00 | .062 | .015 | 3°25 | 68.33 | .464 | .116 |
| 10 | 3.33 | .000 | .000 | 50 | 36.67 | .072 | .018 | 30 | 70.00 | .499 | .125 |
| 15 | 5.00 | .000 | .000 | 55 | 38.33 | .082 | .020 | 35 | 71.67 | .535 | .134 |
| 20 | 6.67 | .000 | .000 | 2°-00 | 40.00 | .093 | .023 | 40 | 73.33 | .573 | .143 |
| 25 | 8.33 | .001 | .000 | 05 | 41.67 | .105 | .026 | 45 | 75.00 | .613 | .153 |
| 30 | 10.00 | .001 | .000 | 10 | 43.33 | .118 | .029 | 50 | 76.67 | .655 | .164 |
| 35 | 11.67 | .002 | .000 | 15 | 45.00 | .133 | .033 | 55 | 78.33 | .698 | .174 |
| 40 | 13.33 | .003 | .000 | 20 | 46.67 | .148 | .037 | 4°00 | 80.00 | .744 | .186 |
| 45 | 15.00 | .005 | .001 | 25 | 48.33 | .164 | .041 | 05 | 81.67 | .792 | .198 |
| 50 | 16.67 | .007 | .002 | 30 | 50.00 | .182 | .045 | 10 | 83.33 | .841 | .210 |
| 55 | 18.33 | .009 | .002 | 35 | 51.67 | .200 | .050 | 15 | 85.00 | .893 | .223 |
| 1°00 | 20.00 | .012 | .003 | 40 | 53.33 | .221 | .055 | 20 | 86.67 | .946 | .236 |
| 05 | 21.67 | .015 | .004 | 45 | 55.00 | .242 | .060 | 25 | 88.33 | 1.002 | .250 |
| 10 | 23.33 | .018 | .004 | 50 | 56.67 | .265 | .066 | 30 | 90.00 | 1.060 | .265 |
| 15 | 25.00 | .023 | .005 | 55 | 58.33 | .289 | .072 | 35 | 91.67 | 1.120 | .280 |
| 20 | 26.67 | .028 | .007 | 3°00 | 60.00 | .314 | .078 | 40 | 93.33 | 1.182 | .295 |
| 25 | 28.33 | .033 | .008 | 05 | 61.67 | .341 | .085 | 45 | 95.00 | 1.246 | .312 |
| 30 | 30.00 | .039 | .009 | 10 | 63.33 | .369 | .092 | 50 | 96.67 | 1.313 | .328 |
| 35 | 31.67 | .046 | .011 | 15 | 65.00 | .399 | .100 | 55 | 98.33 | 1.382 | .346 |
| 40 | 33.33 | .054 | .013 | 20 | 66.67 | .431 | .108 | 5°00 | 100.00 | 1.454 | .364 |

found on railroads in the mountainous districts, there are a number of tables that can be conveniently used; but in the more level districts where the curves are not so sharp and speed of trains greater, the transition curve has been slower in showing its necessity, and the tables now in print are not in convenient form for use.

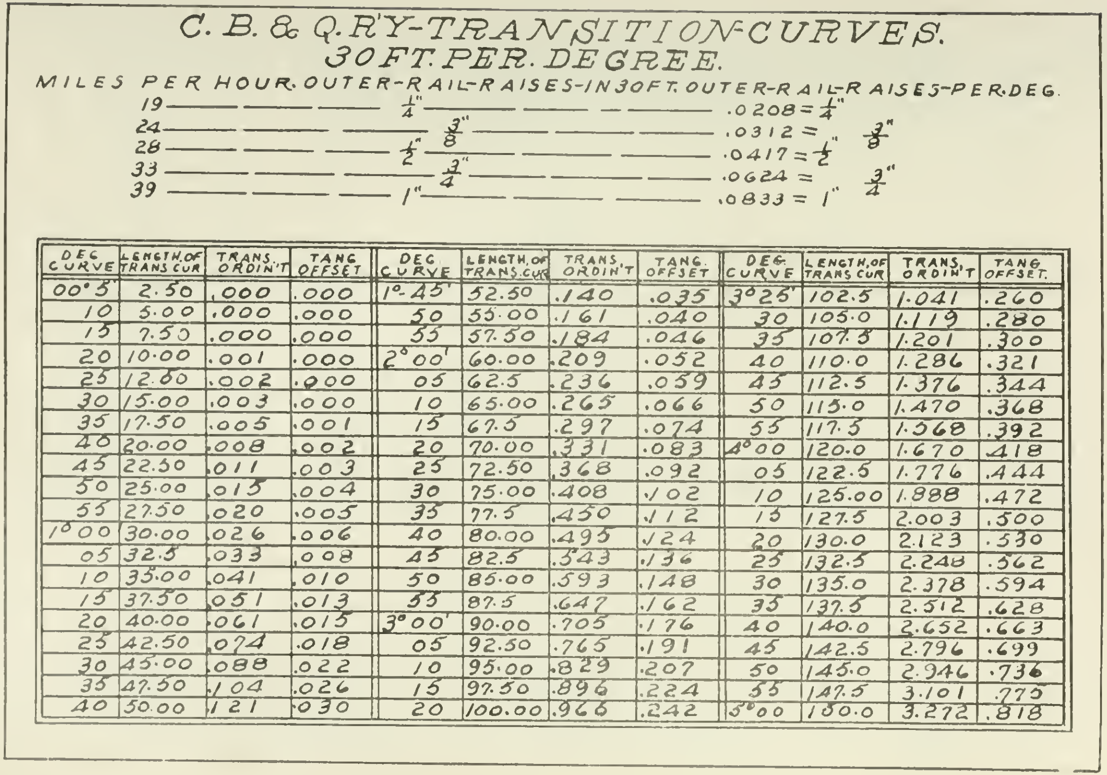


C. B. & Q. R'Y-TRANSITION-CURVES.
25-FT. PER. DEGREE.

| MILES PER HOUR. | OUTER-RAIL-RAISES-IN 30 FT. | OUTER-RAIL-RAISES-PER DEG. |
|---|---|---|
| 18 | $\frac{1}{4}''$ | .0173 = $\frac{7}{32}''$ |
| 22 | $\frac{3}{8}''$ | .026 = $\frac{5}{16}''$ |
| 25 | $\frac{1}{2}''$ | .0346 = $\frac{13}{32}''$ |
| 30 | $\frac{3}{4}''$ | .0520 = $\frac{5}{8}''$ |
| 35 | 1" | .0693 = $\frac{27}{32}''$ |

| DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T. | TANG. OFFSET. | DEG CURVE | LENGTH OF TRANS CUR | TRANS ORDIN'T | TANG. OFFSET | DEG CURVE | LENGTH OF TRANS CUR | TRANS. ORDIN'T. | TANG. OFFSET. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5' | 2.083 | .00 | .00 | 1°45' | 43.745 | .097 | .024 | 3°25 | 85.414 | .723 | .180 |
| 10 | 4.166 | .00 | .00 | 50 | 45.828 | .111 | .027 | 30 | 87.497 | .777 | .194 |
| 15 | 6.248 | .00 | .00 | 55 | 47.911 | .127 | .031 | 35 | 89.580 | .834 | .208 |
| 20 | 8.331 | .00 | .00 | 2°00 | 50.00 | .145 | .036 | 40 | 91.662 | .894 | .223 |
| 25 | 10.414 | .001 | .000 | 05 | 52.083 | .164 | .041 | 45 | 93.745 | .956 | .239 |
| 30 | 12.497 | .002 | .000 | 10 | 54.166 | .184 | .046 | 50 | 95.828 | 1.022 | .255 |
| 35 | 14.579 | .003 | .000 | 15 | 56.248 | .206 | .051 | 55 | 97.911 | 1.090 | .272 |
| 40 | 16.662 | .005 | .001 | 20 | 58.331 | .230 | .057 | 4°00 | 100.00 | 1.161 | .290 |
| 45 | 18.745 | .007 | .001 | 25 | 60.414 | .256 | .064 | 05 | 102.083 | 1.235 | .308 |
| 50 | 20.820 | .010 | .002 | 30 | 62.496 | .283 | .070 | 10 | 104.166 | 1.312 | .328 |
| 55 | 22.911 | .013 | .003 | 35 | 64.580 | .312 | .078 | 15 | 106.248 | 1.393 | .348 |
| 1°00 | 25.00 | .018 | .004 | 40 | 66.662 | .344 | .086 | 20 | 108.331 | 1.476 | .369 |
| 05' | 27.083 | .023 | .005 | 45 | 68.745 | .377 | .094 | 25 | 110.414 | 1.563 | .390 |
| 10 | 29.166 | .028 | .007 | 50 | 70.828 | .412 | .103 | 30 | 112.496 | 1.653 | .413 |
| 15 | 31.248 | .035 | .008 | 55 | 72.911 | .450 | .112 | 35 | 114.579 | 1.746 | .436 |
| 20 | 33.331 | .043 | .010 | 3°00 | 75.000 | .489 | .122 | 40 | 116.662 | 1.844 | .461 |
| 25 | 35.414 | .051 | .012 | 05 | 77.083 | .531 | .132 | 45 | 118.745 | 1.944 | .486 |
| 30 | 37.497 | .061 | .015 | 10 | 79.166 | .576 | .144 | 50 | 120.828 | 2.048 | .512 |
| 35 | 39.579 | .072 | .018 | 15 | 81.248 | .626 | .155 | 55 | 122.911 | 2.156 | .539 |
| 40 | 41.662 | .084 | .021 | 20 | 83.331 | .672 | .168 | 5°00 | 125.000 | 2.272 | .568 |

Probably any of the formulæ for transition curves will answer the requirements for making good track. The tables submitted are figured on the assumption that the offsets from the tangent are proportional to the cubes of the distance from the point of beginning of spiral measured along the curve, the offset being figured



C. B. & Q. R'Y-TRANSITION-CURVES.
30 FT. PER. DEGREE.

MILES PER HOUR. OUTER-RAIL-RAISES-IN 30 FT. OUTER-RAIL-RAISES-PER. DEG.
19 — $\frac{1}{4}''$ — .0208 = $\frac{1}{4}''$
24 — $\frac{3}{8}''$ — .0312 = $\frac{3}{8}''$
28 — $\frac{1}{2}''$ — .0417 = $\frac{1}{2}''$
33 — $\frac{3}{4}''$ — .0624 = $\frac{3}{4}''$
39 — 1″ — .0833 = 1″

| DEG CURVE | LENGTH OF TRANS CUR | TRANS. ORDIN'T | TANG OFFSET | DEG CURVE | LENGTH OF TRANS. CUR | TRANS. ORDIN'T | TANG. OFFSET | DEG CURVE | LENGTH OF TRANS CUR | TRANS. ORDIN'T | TANG OFFSET. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00°5' | 2.50 | .000 | .000 | 1°-45' | 52.50 | .140 | .035 | 3°25' | 102.5 | 1.041 | .260 |
| 10 | 5.00 | .000 | .000 | 50 | 55.00 | .161 | .040 | 30 | 105.0 | 1.119 | .280 |
| 15 | 7.50 | .000 | .000 | 55 | 57.50 | .184 | .046 | 35 | 107.5 | 1.201 | .300 |
| 20 | 10.00 | .001 | .000 | 2°00' | 60.00 | .209 | .052 | 40 | 110.0 | 1.286 | .321 |
| 25 | 12.60 | .002 | .000 | 05 | 62.5 | .236 | .059 | 45 | 112.5 | 1.376 | .344 |
| 30 | 15.00 | .003 | .000 | 10 | 65.00 | .265 | .066 | 50 | 115.0 | 1.470 | .368 |
| 35 | 17.50 | .005 | .001 | 15 | 67.5 | .297 | .074 | 55 | 117.5 | 1.568 | .392 |
| 40 | 20.00 | .008 | .002 | 20 | 70.00 | .331 | .083 | 4°00 | 120.0 | 1.670 | .418 |
| 45 | 22.50 | .011 | .003 | 25 | 72.50 | .368 | .092 | 05 | 122.5 | 1.776 | .444 |
| 50 | 25.00 | .015 | .004 | 30 | 75.00 | .408 | .102 | 10 | 125.00 | 1.888 | .472 |
| 55 | 27.50 | .020 | .005 | 35 | 77.5 | .450 | .112 | 15 | 127.5 | 2.003 | .500 |
| 1°00 | 30.00 | .026 | .006 | 40 | 80.00 | .495 | .124 | 20 | 130.0 | 2.123 | .530 |
| 05 | 32.5 | .033 | .008 | 45 | 82.5 | .543 | .136 | 25 | 132.5 | 2.248 | .562 |
| 10 | 35.00 | .041 | .010 | 50 | 85.00 | .593 | .148 | 30 | 135.0 | 2.378 | .594 |
| 15 | 37.50 | .051 | .013 | 55 | 87.5 | .647 | .162 | 35 | 137.5 | 2.512 | .628 |
| 20 | 40.00 | .061 | .015 | 3°00' | 90.00 | .705 | .176 | 40 | 140.0 | 2.652 | .663 |
| 25 | 42.50 | .074 | .018 | 05 | 92.50 | .765 | .191 | 45 | 142.5 | 2.796 | .699 |
| 30 | 45.00 | .088 | .022 | 10 | 95.00 | .829 | .207 | 50 | 145.0 | 2.946 | .736 |
| 35 | 47.50 | .104 | .026 | 15 | 97.50 | .896 | .224 | 55 | 147.5 | 3.101 | .775 |
| 40 | 50.00 | .121 | .030 | 20 | 100.00 | .966 | .242 | 5°00 | 150.0 | 3.272 | .818 |
]

for the 5-degree curve, which is the largest shown, by considering the curve and chord as the same length, and the other offsets proportional to this. While not strictly true, these assumptions are sufficiently accurate for all ordinary cases.

## C. B. & Q. RY-TRANSITION-CURVES.

### 40 FT. PER. DEGREE.

| MILES PER HOUR. | OUTER-RAIL-RAISES-IN 30 FT | OUTER-RAIL-RAISES-PER DEG. |
|---|---|---|
| 23 | 1/4" | .0278 = 11/32" |
| 28 | 3/8" | .0417 = 1/2" |
| 31 | 1/2" | .0556 = 21/32" |
| 39 | 3/4" | .0833 = 1" |
| 45 | 1" | .1111 = 1 11/32" |

| DEG CURVE | LENGTH OF TRANS. CUR | TRANS ORDIN'T | TANG OFFSET | DEG. CURVE | LENGTH, OF TRANS. CUR | TRANS. ORDIN'T | TANG OFFSET | DEG CURVE | LENGTH, OF TRANS. CUR | TRANS. ORDIN'T | TANG OFFSET |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00°5' | 3.33 | .000 | .000 | 1° 45 | 70.00 | .249 | .062 | 3° 25' | 136.67 | 1.854 | .463 |
| 10 | 6.67 | .000 | .000 | 50 | 73.33 | .286 | .071 | 30 | 140.00 | 1.993 | .498 |
| 15 | 10.00 | .001 | .000 | 55 | 76.67 | .327 | .082 | 35 | 143.33 | 2.138 | .534 |
| 20 | 13.33 | .002 | .000 | 2°00 | 80.00 | .372 | .093 | 40 | 146.67 | 2.291 | .573 |
| 25 | 16.67 | .003 | .001 | 05 | 83.33 | .420 | .105 | 45 | 150.00 | 2.451 | .613 |
| 30 | 20.00 | .006 | .002 | 10 | 86.67 | .473 | .118 | 50 | 153.33 | 2.618 | .654 |
| 35 | 23.33 | .009 | .002 | 15 | 90.00 | .529 | .132 | 55 | 156.67 | 2.793 | .698 |
| 40 | 26.67 | .014 | .003 | 20 | 93.33 | .591 | .148 | 4°00 | 160.00 | 2.975 | .744 |
| 45 | 30.00 | .019 | .005 | 25 | 96.67 | .656 | .164 | 05 | 163.33 | 3.165 | .791 |
| 50 | 33.33 | .027 | .007 | 30 | 100.00 | .726 | .181 | 10 | 166.67 | 3.363 | .841 |
| 55 | 36.67 | .036 | .009 | 35 | 103.33 | .801 | .200 | 15 | 170.00 | 3.568 | .892 |
| 1°00 | 40.00 | .046 | .011 | 40 | 106.67 | .881 | .220 | 20 | 173.33 | 3.782 | .945 |
| 1°05 | 43.33 | .059 | .015 | 45 | 110.00 | .967 | .242 | 25 | 176.67 | 4.005 | 1.001 |
| 10 | 46.67 | .074 | .018 | 50 | 113.33 | 1.057 | .264 | 30 | 180.00 | 4.236 | 1.059 |
| 15 | 50.00 | .091 | .023 | 55 | 116.67 | 1.153 | .288 | 36 | 183.33 | 4.475 | 1.119 |
| 20 | 53.33 | .110 | .028 | 3°00 | 120.00 | 1.255 | .314 | 40 | 186.67 | 4.724 | 1.181 |
| 25 | 56.67 | .132 | .033 | 05 | 123.33 | 1.362 | .340 | 45 | 190.00 | 4.982 | 1.245 |
| 30 | 60.00 | .157 | .039 | 10 | 126.67 | 1.476 | .369 | 50 | 193.33 | 5.248 | 1.312 |
| 35 | 63.33 | .185 | .046 | 15 | 130.00 | 1.596 | .399 | 55 | 196.67 | 5.525 | 1.381 |
| 40 | 66.67 | .215 | .054 | 20 | 133.33 | 1.722 | .430 | 5°00 | 200.00 | 5816 | 1.454 |

The length of the transition curve should depend upon the speed of trains using it. As the outer rail on simple curves is elevated for a chosen speed, and as the customary practice is to ease off this elevation at each end of the curve at a fixed rate per rail length, usually ½ inch—as stated by Mr. Torrance—it therefore follows

## C. B. & Q. R'Y.-TRANSITION-CURVES.

### 50 FT. PER. DEGREE.

MILES PER HOUR: OUTER-RAIL-RAISES-IN 30 FT.-OUTER-RAIL-RAISES-PER DEG.
25 — — — ¼" — — — .0347 = 13/32"
30 — — — 3/8" — — — .052 = 5/8"
35 — — — ½" — — — .069 = 27/32"
44 — — — ¾" — — — .1040 = 1¼"
50 — — — 1" — — — .1388 = 1 21/32"

| DEG CURVE | LENGTH OF TRANS CUR. | TRANS. ORDIN'T | TANG OFFSET. | DEG CURVE | LENGTH OF TRANS. CUR | TRANS. ORDIN'T. | TANG. OFFSET. | DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T | TANG. OFFSET. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00°–5 | 4.166 | .000 | .000 | 1°–45' | 87.5000 | .390 | .0975 | 3°–25' | 170.833 | 2.900 | .725 |
| 10 | 8.333 | .000 | .000 | 50 | 91.667 | .448 | .112 | 30 | 175.000 | 3.118 | .779 |
| 15 | 12.500 | .001 | .000 | 55 | 95.833 | .512 | .128 | 35 | 179.167 | 3.345 | .836 |
| 20 | 16.668 | .002 | .000 | 2° 00 | 100.000 | .582 | .145 | 40 | 183.333 | 3.584 | .896 |
| 25 | 20.833 | .005 | .001 | 05 | 104.167 | .657 | .164 | 45 | 187.500 | 3.834 | .958 |
| 30 | 25.000 | .009 | .002 | 10 | 108.333 | .740 | .185 | 50 | 191.667 | 4.096 | 1.024 |
| 35 | 29.167 | .014 | .003 | 15 | 112.500 | .828 | .207 | 55 | 195.833 | 4.369 | 1.092 |
| 40 | 33.333 | .021 | .005 | 20 | 116.667 | .920 | .230 | 4° 00 | 200.000 | 4.654 | 1.163 |
| 45 | 37.500 | .030 | .007 | 25 | 120.833 | 1.026 | .256 | 05 | 204.166 | 4.950 | 1.237 |
| 50 | 41.667 | .042 | .010 | 30 | 125.000 | 1.136 | .284 | 10 | 208.333 | 5.260 | 1.315 |
| 55 | 45.833 | .056 | .014 | 35 | 129.167 | 1.253 | .313 | 15 | 212.500 | 5.580 | 1.395 |
| 1° 00 | 50.000 | .072 | .018 | 40 | 133.333 | 1.379 | .345 | 20 | 216.667 | 5.918 | 1.479 |
| 05 | 54.1667 | .093 | .023 | 45 | 137.500 | 1.512 | .378 | 25 | 220.833 | 6.265 | 1.566 |
| 10 | 58.333 | .115 | .028 | 50 | 141.667 | 1.654 | .413 | 30 | 225.000 | 6.626 | 1.656 |
| 15 | 62.500 | .142 | .035 | 55 | 145.83 | 1.804 | .451 | 35 | 229.167 | 7.001 | 1.750 |
| 20 | 66.667 | .172 | .043 | 3° 00 | 150.000 | 1.963 | .491 | 40 | 233.333 | 7.390 | 1.847 |
| 25 | 70.833 | .206 | .051 | 05 | 154.167 | 2.131 | .533 | 45 | 237.500 | 7.793 | 1.948 |
| 30 | 75.000 | .245 | .061 | 10 | 158.333 | 2.309 | .577 | 50 | 241.667 | 8.210 | 2.052 |
| 35 | 79.167 | .288 | .072 | 15 | 162.500 | 2.496 | .624 | 55 | 245.833 | 8.642 | 2.160 |
| 40 | 83.333 | .336 | .084 | 20 | 166.667 | 2.693 | .673 | 5° 00 | 250.000 | 9.089 | 2.272 |

that the length of the transition curve should be fixed by the amount of elevation in the simple curve, which in turn is fixed by the speed of the trains. For instance, the table for a transition curve 100 feet long gives 1 21/32 inches of elevation for each degree of curvature, if the outer rail is raised ½ inch for each thirty

## C. B. & Q. R'Y-TRANSITION-CURVES.

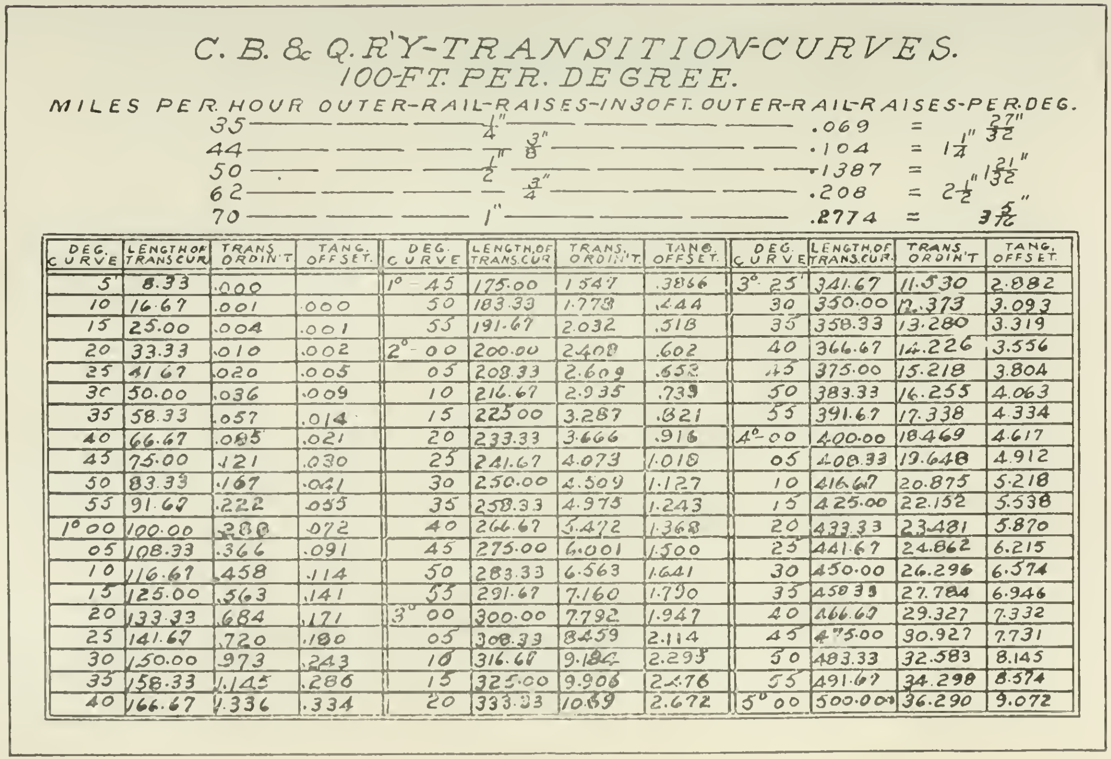
### 75 FT. PER. DEGREE.

| MILES PER HOUR. | OUTER-RAIL-RAISES-IN 30 FT. | OUTER-RAIL-RAISES-PER. DEG. |
|---|---|---|
| 30 | $\frac{1}{4}''$ | .052 = $\frac{5}{8}''$ |
| 37 | $\frac{3}{8}''$ | .078 = $\frac{15}{16}''$ |
| 44 | $\frac{1}{2}''$ | .104 = $1\frac{1}{4}''$ |
| 53 | $\frac{3}{4}''$ | .156 = $1\frac{7}{8}''$ |
| 61 | 1" | .208 = $2\frac{1}{2}''$ |

| DEG CURVE | LENGTH, OF TRANS. CUR. | TRANS. ORDIN'T. | TANG. OFFSET. | DEG. CURVE. | LENGTH, OF TRANS. CUR. | TRANS. ORDIN'T. | TANG. OFFSET. | DEG. CURVE | LENGTH, OF TRANS. CUR. | TRANS. ORDIN'T. | TANG. OFFSET. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5' | 6.25 | .000 | | 1°-45' | 131.25 | .872 | .218 | 3°-25' | 256.25 | 6492 | 1.623 |
| 10' | 12.50 | .000 | .000 | 50 | 137.50 | 1.003 | .250 | 30 | 262.50 | 7.279 | 1.819 |
| 15' | 18.75 | .002 | .000 | 55 | 143.75 | 1.146 | .286 | 35 | 268.75 | 7.489 | 1.872 |
| 20' | 25.00 | .006 | .001 | 2°-00 | 150.00 | 1.302 | .325 | 40 | 275.00 | 8.024 | 2.006 |
| 25' | 31.25 | .011 | .003 | 05 | 156.25 | 1.471 | .368 | 45 | 281.25 | 8.584 | 2.146 |
| 30' | 37.50 | .020 | .005 | 10 | 162.50 | 1.655 | .413 | 50 | 287.50 | 9.169 | 2.292 |
| 35' | 43.75 | .032 | .008 | 15 | 168.75 | 1.854 | .463 | 55 | 293.75 | 9.780 | 2.443 |
| 40' | 50.00 | .048 | .012 | 20 | 175.00 | 2.067 | .517 | 4°.00 | 300.00 | 10.417 | 2.604 |
| 45 | 56.25 | .068 | .017 | 25 | 181.25 | 2.297 | .574 | 05 | 306.25 | 11.082 | 2.770 |
| 50 | 62.50 | .094 | .023 | 30 | 187.50 | 2.543 | .635 | 10 | 312.50 | 11.775 | 2.943 |
| 55 | 68.75 | .125 | .031. | 35 | 193.75 | 2.806 | .701. | 15 | 318.75 | 12.495 | 3.124 |
| 1°00 | 75.00 | .162 | .040 | 40 | 200.00 | 3.086 | .771 | 20 | 325.00 | 13.245 | 3.311 |
| 05 | 81.25 | .207 | .051 | 45 | 206.25 | 3.385 | .846 | 25 | 331.25 | 14.024 | 3.506 |
| 10 | 87.50 | .258 | .064 | 50 | 212.50 | 3.692 | .923 | 30 | 337.50 | 14.833 | 3.708 |
| 15 | 93.75 | .317. | .079 | 55 | 218.75 | 4.039 | 1.002 | 35 | 343.75 | 15.673 | 3.918 |
| 20 | 100.00 | .385 | .096 | 3° 00 | 225.00 | 4.395 | 1.098 | 40 | 350.00 | 16.543 | 4.136 |
| 25 | 106.25 | .462 | .115 | 05 | 231.25 | 4.772 | 1.192 | 45 | 356.25 | 17.445 | 4.361 |
| 30 | 112.50 | .549 | .137 | 10 | 237.50 | 5.169 | 1.292 | 50 | 362.50 | 18.379 | 4.595 |
| 35 | 118.75 | .646 | .161. | 15 | 243.75 | 5.588 | 1.397 | 55 | 368.75 | 19.346 | 4.837 |
| 40 | 125.00 | .753 | .188. | 20 | 250.00 | 6.029 | 1.507 | 5°00 | 375.00 | 20.357 | 5.089 |

feet. This 1 21/32 inches is the elevation of the outer rail for a speed of fifty miles per hour.

Likewise, if the outer rail is raised at the rate of ¼ inch for every thirty feet of transition curve, the total raise will be 27/32 of an inch, corresponding to a speed of thirty-five miles per hour.



## C. B. & Q. R'Y-TRANSITION-CURVES.

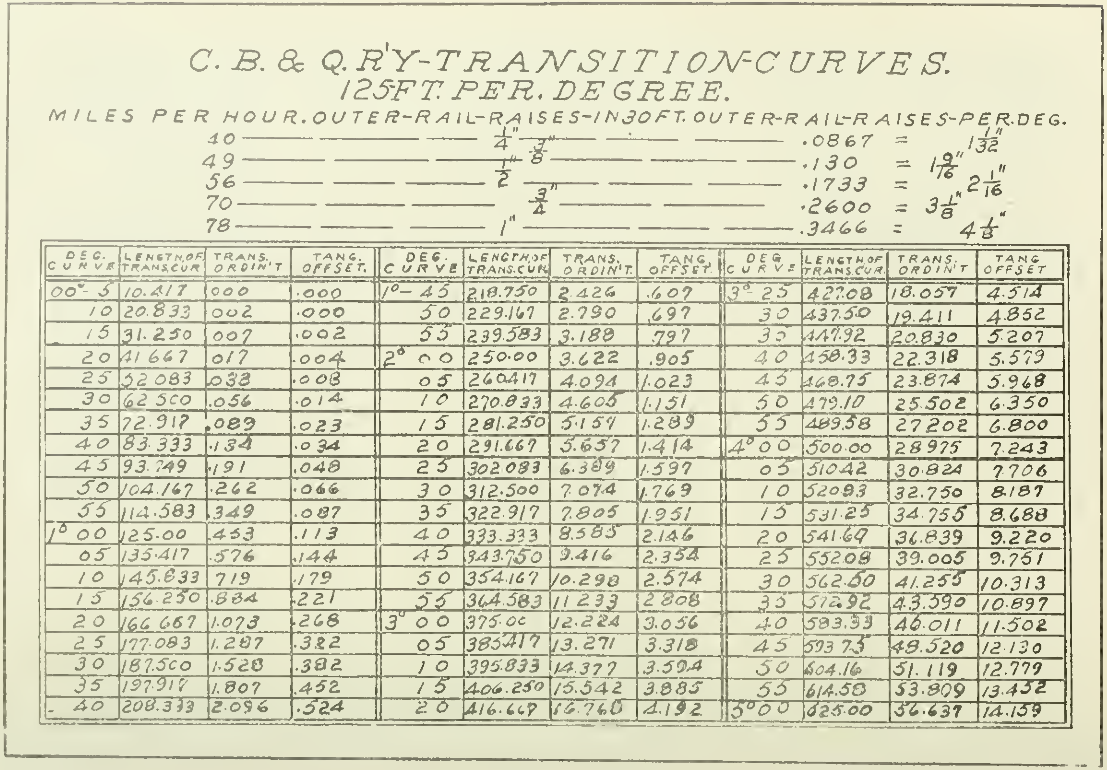
### 100-FT. PER. DEGREE.

MILES PER HOUR OUTER-RAIL-RAISES-IN 30 FT. OUTER-RAIL-RAISES-PER DEG.

35 — $\frac{1}{4}''$ — .069 = $\frac{27}{32}''$
44 — $\frac{3}{8}''$ — .104 = $1\frac{1}{4}''$
50 — $\frac{1}{2}''$ — .1387 = $1\frac{21}{32}''$
62 — $\frac{3}{4}''$ — .208 = $2\frac{1}{2}''$
70 — $1''$ — .2774 = $3\frac{5}{16}''$

| DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T | TANG. OFFSET. | DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T. | TANG. OFFSET. | DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T | TANG. OFFSET. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5' | 8.33 | .000 | | 1° 45 | 175.00 | 1.547 | .3866 | 3° 25' | 341.67 | 11.530 | 2.882 |
| 10 | 16.67 | .001 | .000 | 50 | 183.33 | 1.778 | .444 | 30 | 350.00 | 12.373 | 3.093 |
| 15 | 25.00 | .004 | .001 | 55 | 191.67 | 2.032 | .518 | 35 | 358.33 | 13.280 | 3.319 |
| 20 | 33.33 | .010 | .002 | 2° 00 | 200.00 | 2.408 | .602 | 40 | 366.67 | 14.226 | 3.556 |
| 25 | 41.67 | .020 | .005 | 05 | 208.33 | 2.609 | .652 | 45 | 375.00 | 15.218 | 3.804 |
| 30 | 50.00 | .036 | .009 | 10 | 216.67 | 2.935 | .739 | 50 | 383.33 | 16.255 | 4.063 |
| 35 | 58.33 | .057 | .014 | 15 | 225.00 | 3.287 | .821 | 55 | 391.67 | 17.338 | 4.334 |
| 40 | 66.67 | .085 | .021 | 20 | 233.33 | 3.666 | .916 | 4° 00 | 400.00 | 18.469 | 4.617 |
| 45 | 75.00 | .121 | .030 | 25 | 241.67 | 4.073 | 1.018 | 05 | 408.33 | 19.648 | 4.912 |
| 50 | 83.33 | .167 | .041 | 30 | 250.00 | 4.509 | 1.127 | 10 | 416.67 | 20.875 | 5.218 |
| 55 | 91.67 | .222 | .055 | 35 | 258.33 | 4.975 | 1.243 | 15 | 425.00 | 22.152 | 5.538 |
| 1° 00 | 100.00 | .288 | .072 | 40 | 266.67 | 5.472 | 1.368 | 20 | 433.33 | 23.481 | 5.870 |
| 05 | 108.33 | .366 | .091 | 45 | 275.00 | 6.001 | 1.500 | 25 | 441.67 | 24.862 | 6.215 |
| 10 | 116.67 | .458 | .114 | 50 | 283.33 | 6.563 | 1.641 | 30 | 450.00 | 26.296 | 6.574 |
| 15 | 125.00 | .563 | .141 | 55 | 291.67 | 7.160 | 1.790 | 35 | 458.33 | 27.784 | 6.946 |
| 20 | 133.33 | .684 | .171 | 3° 00 | 300.00 | 7.792 | 1.947 | 40 | 466.67 | 29.327 | 7.332 |
| 25 | 141.67 | .720 | .180 | 05 | 308.33 | 8.459 | 2.114 | 45 | 475.00 | 30.927 | 7.731 |
| 30 | 150.00 | .973 | .243 | 10 | 316.67 | 9.184 | 2.293 | 50 | 483.33 | 32.583 | 8.145 |
| 35 | 158.33 | 1.145 | .286 | 15 | 325.00 | 9.906 | 2.476 | 55 | 491.67 | 34.298 | 8.574 |
| 40 | 166.67 | 1.336 | .334 | 20 | 333.33 | 10.69 | 2.672 | 5° 00 | 500.00 | 36.290 | 9.072 |

Hence this table of 100 feet for each degree of curvature in the circular curve should be used for a speed of thirty-five miles per hour if the outer rail is raised at the rate of ¼ inch in thirty feet, or forty-four miles per hour if the outer rail is raiser at the rate of ⅜ inch



C. B. & Q. R'Y-TRANSITION-CURVES.
125 FT. PER. DEGREE.

MILES PER HOUR. OUTER-RAIL-RAISES-IN 30 FT. OUTER-RAIL-RAISES-PER DEG.
40 — — — 1/4" — — — .0867 = 1 1/32"
49 — — — 3/8" — — — .130 = 1 9/16"
56 — — — 1/2" — — — .1733 = 2 1/16"
70 — — — 3/4" — — — .2600 = 3 1/8"
78 — — — 1" — — — .3466 = 4 1/8"

| DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T | TANG. OFFSET. | DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T. | TANG. OFFSET. | DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T | TANG. OFFSET |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00°- 5 | 10.417 | 000 | .000 | 1°- 45 | 218.750 | 2.426 | .607 | 3°- 25 | 427.08 | 18.057 | 4.514 |
| 10 | 20.833 | 002 | .000 | 50 | 229.167 | 2.790 | .697 | 30 | 437.50 | 19.411 | 4.852 |
| 15 | 31.250 | 007 | .002 | 55 | 239.583 | 3.188 | .797 | 35 | 447.92 | 20.830 | 5.207 |
| 20 | 41 667 | 017 | .004 | 2° 00 | 250.00 | 3.622 | .905 | 40 | 458.33 | 22.318 | 5.579 |
| 25 | 52 083 | .038 | .008 | 05 | 260.417 | 4.094 | 1.023 | 45 | 468.75 | 23.874 | 5.968 |
| 30 | 62 500 | .056 | .014 | 10 | 270.833 | 4.605 | 1.151 | 50 | 479.10 | 25.502 | 6.350 |
| 35 | 72.917 | .089 | .023 | 15 | 281.250 | 5.157 | 1.289 | 55 | 489.58 | 27 202 | 6.800 |
| 40 | 83.333 | .134 | .034 | 20 | 291.667 | 5.657 | 1.414 | 4° 00 | 500.00 | 28 975 | 7.243 |
| 45 | 93.749 | .191 | .048 | 25 | 302.083 | 6.389 | 1.597 | 05 | 510.42 | 30.824 | 7.706 |
| 50 | 104.167 | .262 | .066 | 30 | 312.500 | 7.074 | 1.769 | 10 | 520.83 | 32.750 | 8.187 |
| 55 | 114.583 | .349 | .087 | 35 | 322.917 | 7.805 | 1.951 | 15 | 531.25 | 34.755 | 8.688 |
| 1° 00 | 125.00 | .453 | .113 | 40 | 333.333 | 8.585 | 2.146 | 20 | 541.67 | 36.839 | 9.220 |
| 05 | 135.417 | .576 | .144 | 45 | 343.750 | 9.416 | 2.354 | 25 | 552.08 | 39.005 | 9.751 |
| 10 | 145.833 | 719 | .179 | 50 | 354.167 | 10.298 | 2.574 | 30 | 562.50 | 41.255 | 10.313 |
| 15 | 156.250 | .884 | .221 | 55 | 364.583 | 11 233 | 2 808 | 35 | 572.92 | 43.590 | 10.897 |
| 20 | 166 667 | 1.073 | .268 | 3° 00 | 375.00 | 12.224 | 3.056 | 40 | 583.33 | 46.011 | 11.502 |
| 25 | 177.083 | 1.287 | .322 | 05 | 385.417 | 13.271 | 3.318 | 45 | 593.75 | 48.520 | 12.130 |
| 30 | 187.500 | 1.528 | .382 | 10 | 395.833 | 14.377 | 3.594 | 50 | 604.16 | 51.119 | 12.779 |
| 35 | 197.917 | 1.807 | .452 | 15 | 406.250 | 15.542 | 3.885 | 55 | 614.58 | 53.809 | 13.432 |
| 40 | 208.333 | 2.096 | .524 | 20 | 416.667 | 16.760 | 4.192 | 5° 00 | 625.00 | 56.637 | 14.159 |

in thirty feet, or fifty miles per hour if the outer rail is raised at the rate of ½ inch in thirty feet, or sixty miles per hour if the outer rail is raised at the rate of ¾ inch in thirty feet, when the simple curve is given the proper elevation for these speeds.

## C. B. & Q. RY-TRANSITION-CURVES.

### 150 FT. PER. DEGREE.

MILES PER HOUR. OUTER-RAIL-RAISES-IN 30 FT. OUTER-RAIL-RAISES-PER. DEG.
44 —— ¼" —— .1040 = 1¼"
53 —— ⅜" —— .156 = 1⅞"
61 —— ½" —— .2080 = 2½"
75 —— ¾" —— .3120 = 3¾"
86 —— 1" —— .416 = 5"

| DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T | TANG. OFFSET | DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T | TANG. OFFSET. | DEG. CURVE | LENGTH OF TRANS. CUR. | TRANS. ORDIN'T. | TANG. OFFSET. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00°5' | 12.5 | .000 | .000 | 1°-45' | 262.50 | 3.491 | .873 | 3°-25' | 512.50 | 25.983 | 6.496 |
| 10 | 25.00 | .003 | .000 | 50 | 275.00 | 4.014 | 1.004 | 30 | 525.00 | 27.932 | 6.983 |
| 15 | 37.50 | .010 | .002 | 55 | 287.50 | 4.587 | 1.147 | 35 | 537.50 | 29.974 | 7.494 |
| 20 | 50.00 | .024 | .006 | 2° 00 | 300.00 | 5.212 | 1.303 | 40 | 550.00 | 32.114 | 8.029 |
| 25 | 62.50 | .047 | .012 | 05 | 312.50 | 5.091 | 1.498 | 45 | 562.50 | 34.354 | 8.689 |
| 30 | 75.00 | .081 | .020 | 10 | 325.00 | 6.626 | 1.657 | 50 | 575.00 | 36.696 | 9.174 |
| 35 | 87.50 | .129 | .032 | 15 | 337.50 | 7.421 | 1.855 | 55 | 587.50 | 39.141 | 9.785 |
| 40 | 100.00 | .193 | .048 | 20 | 350.00 | 8.276 | 2.069 | 4° 00 | 600.00 | 41.693 | 10.423 |
| 45 | 112.50 | .275 | .069 | 25 | 362.50 | 9.195 | 2.297 | 05 | 612.50 | 44.354 | 11.088 |
| 50 | 125.00 | .377 | .094 | 30 | 375.00 | 10.179 | 2.545 | 10 | 625.00 | 47.125 | 11.781 |
| 55 | 137.50 | .502 | .125 | 35 | 387.500 | 11.231 | 2.808 | 15 | 637.50 | 50.009 | 12.502 |
| 1° 00 | 150.00 | .658 | .164 | 40 | 400.00 | 12.354 | 3.088 | 20 | 650.00 | 53.009 | 13.252 |
| 05 | 162.50 | .828 | .207 | 45 | 412.50 | 13.548 | 3.387 | 25 | 662.50 | 56.127 | 14.032 |
| 10 | 175.00 | 1.035 | .259 | 50 | 425.00 | 14.818 | 3.704 | 30 | 675.00 | 59.364 | 14.841 |
| 15 | 187.50 | 1.272 | .318 | 55 | 437.50 | 16.164 | 4.041 | 35 | 687.50 | 63.723 | 15.931 |
| 20 | 200.00 | 1.544 | .386 | 3° 00 | 450.00 | 17.589 | 4.397 | 40 | 700.00 | 66.207 | 16.552 |
| 25 | 212.50 | 1.851 | .463 | 05 | 462.50 | 19.096 | 4.774 | 45 | 712.50 | 69.718 | 17.429 |
| 30 | 225.00 | 2.199 | .550 | 10 | 475.00 | 20.687 | 5.172 | 50 | 725.00 | 73.557 | 18.389 |
| 35 | 237.50 | 2.586 | .646 | 15 | 487.50 | 22.363 | 5.591 | 55 | 737.50 | 77.428 | 19.357 |
| 40 | 250.00 | 3.016 | .754 | 20 | 500.00 | 24.128 | 6.032 | 5° 00 | 750.00 | 81.450 | 20.363 |

In a corresponding manner, if the practice of using ½ an inch raise of the outer rail in thirty feet is decided upon, and track for a speed of twenty-nine miles per hour is wanted, the table of twenty-five feet per degree should be used:

## C. B. & Q. R'Y.-TRANSITION-CURVES.

### 175-FT. PER. DEGREE.

MILES PER HOUR. OUTER-RAIL-RAISES-IN 30 FT. OUTER-RAIL-RAISES-PER. DEG.

47 ——— $\frac{1}{4}''$ ——— .1213 = $1\frac{15}{32}''$
58 ——— $\frac{3}{8}''$ ——— .182 = $2\frac{3}{16}$
66 ——— $\frac{1}{2}''$ ——— .2427 = $2\frac{29}{32}''$
80 ——— $\frac{3}{4}''$ ——— .3640 = $4\frac{3}{8}''$
94 $1''$ 4854 = $5\frac{13}{16}''$

| DEG. CURVE | LENGTH, OF TRANS. CUR | TRANS. ORDIN'T. | TANG. OFFSET | DEG CURVE | LENGTH, OF TRANS. CUR | TRANS. ORDIN'T. | TANG. OFFSET. | DEG. CURVE | LENGTH, OF TRANS. CUR | TRANS. ORDIN'T. | TANG. OFFSET. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0°05 | 14.58 | .000 | .000 | 1°—45' | 306.25 | 4.745 | 1.186 | 3°—25 | 597.92 | 35.315 | 8.828 |
| 10 | 29.17 | .004 | .001 | 50 | 320.83 | 5456 | 1.364 | 30 | 612.50 | 37.963 | 9.491 |
| 15 | 43.75 | .014 | .003 | 55 | 335.42 | 6.234 | 1.559 | 35 | 627.08 | 40.740 | 10.185 |
| 20 | 58.33 | .033 | .008 | 2°—00 | 350.00 | 7.083 | 1.771 | 40 | 641.67 | 43.648 | 10.912 |
| 25 | 72.92 | .064 | .016 | 05 | 364.58 | 8.006 | 2.002 | 45 | 656.25 | 46.693 | 11.673 |
| 30 | 87.50 | .111 | .028 | 10 | 379.17 | 9.006 | 2.252 | 50 | 670.83 | 49.875 | 12.468 |
| 35 | 102.08 | .175 | .044 | 15 | 393.75 | 10.086 | 2.521 | 55 | 685.42 | 53.200 | 13.300 |
| 40 | 116.67 | .262 | .066 | 20 | 408.33 | 11.249 | 2.812 | 4°00 | 700.00 | 56.667 | 14.167 |
| 45 | 131.25 | .374 | .093 | 25 | 422.92 | 12.500 | 3.124 | 05 | 714.58 | 60.283 | 15.071 |
| 50 | 145.83 | .512 | .128 | 30 | 437.50 | 13.835 | 3.459 | 10 | 729.17 | 64.050 | 16.013 |
| 55 | 160.42 | .682 | .171 | 35 | 452.08 | 15.265 | 3.816 | 15 | 743.75 | 67.970 | 16.993 |
| 1°00 | 175.00 | .885 | .221 | 40 | 466.67 | 16.790 | 4.198 | 20 | 758.33 | 72.048 | 18.012 |
| 05 | 189.58 | 1.126 | .281 | 45 | 481.25 | 18.414 | 4.604 | 25 | 772.92 | 76.285 | 19.071 |
| 10 | 204.17 | 1.406 | .352 | 50 | 495.83 | 20.139 | 5.035 | 30 | 787.50 | 80.685 | 20.171 |
| 15 | 218.75 | 1.729 | .432 | 55 | 510.42 | 21.970 | 5.492 | 35 | 802.08 | 85.251 | 21.313 |
| 20 | 233.33 | 2.100 | .525 | 3°00 | 525.00 | 23.907 | 5.977 | 40 | 816.67 | 89.986 | 22.496 |
| 25 | 247.92 | 2.517 | .629 | 05 | 539.58 | 25.955 | 6.488 | 45 | 831.25 | 94.893 | 23.723 |
| 30 | 262.50 | 2.988 | .747 | 10 | 554.17 | 28.116 | 7.029 | 50 | 845.83 | 99.975 | 25.000 |
| 35 | 277.08 | 3.515 | .880 | 15 | 568.75 | 30.395 | 7.600 | 55 | 860.42 | 105.236 | 26.310 |
| 40 | 291.67 | 4.100 | 1.025 | 20 | 583.33 | 32.794 | 8.198 | 5°00 | 875.00 | 110.682 | 27.670 |

| | | | | |
|---|---|---|---|---|
| For a speed of | 35 | miles per hour, | 50 | feet per degree. |
| “ “ “ | 44 | “ “ “ | 75 | “ “ “ |
| “ “ “ | 50 | “ “ “ | 100 | “ “ “ |
| “ “ “ | 56 | “ “ “ | 125 | “ “ “ |
| “ “ “ | 61 | “ “ “ | 150 | “ “ “ |
| “ “ “ | 66 | “ “ “ | 175 | “ “ “ |

As the radius of curvature of the spiral increases in proportion to the distance from point of spiral, the same transition curve for a 1° curve can be used for a 1° 30′ curve or a 2° curve by merely lengthening the transition curve. Advantage has been taken of this principle in these tables, so that in staking out the curve the direct offset to the transition curve from the tangent produced is shown in the third column for a distance from the point of spiral shown in the second column. This gives a sufficient number of points on the spiral for staking without any figuring whatever in the field. This was the idea in mind when making these tables, that no figuring should be necessary when doing the field work, more than for the usual simple curve.

On account of local conditions, we cannot always use the curve which is theoretically the best in any location, but have to approximate it as nearly as may be. For instance, sharp reverse curves may necessitate short transition curves, but usually where there are these conditions the speed is slower and helps to compensate. Likewise, the distance the track can be thrown at a reasonable expense also limits the length of the transition curve; but *any* transition curve where there is high speed is better than none. The same conditions do not govern on new location, and transition curves should always be provided for. As the western roads are nearly all built without transition curves, the subject of relining curves on the main track is closely connected with putting in transition curves. The following are some instructions I have been issuing for some time past when putting a new man on the work:

### INSTRUCTIONS.

“In running curves in the old main track, it is usually preferable to run a trial curve around the old main, rather than to run out the semi-tangents. To do this, first approximate the degree of curve by testing it on some point on the curve. The middle ordinate, in feet, of a chord 214′ represents the degree of curve. Fix the tangent of the straight track at each end of the curve and assume some point as the point of curve. Run the curve around for any reasonable distance and check the distance to the center of the track. This distance represents the sine of the angle of the curve at this point; the radius to which will be the distance to move forward or back with the point of curve, according to whether the curve just run is inside or outside of the center of the track. By one or two trials the point of curve can readily be found which will join the two tangents at the ends of the curve. The angles of the track at the farther end of the curve with the point assumed for the point of tangent should be read and the exact point of tangent figured from this angle. After the location of the assumed curve has been found with reference to the center of the track by thus running it around, the exact degree of curve which will admit of the track being thrown the least possible should then be figured To figure this the external secant of the assumed curve should be figured and the degree of curve which will pass through the center of the track figured by taking the necessary external secant. Not only should the location of the curve with reference to the track at the center point be noted, but also at the quarters and at any other point on the curve where the assumed curve is at a considerable distance from the center of the track. The aim should be to throw the track in and out an equal amount. To do this the best curve may not pass through the center of the track at the center of the curve, but inside or outside of this center, and good judgment should be used in choosing the best curve.

"When the final curve is run, the position of the curve with reference to the nearest mile post should be noted and entered in the note book. The distance and direction of the center of the curve from the center of the track at each station should be taken and entered in the note book. If possible, all curves should be run so as to throw the track but a few inches. When there is an extreme amount of throw the division engineer should be notified and full notes of the curve as run with reference to the center of the track should be sent him.

"Stakes should be set every 50′ on the curve, and on the adjacent tangents every 100′ to 200′ for a reasonable distance to line up tangents, care being taken that the end stakes are set at the center of the track.

"In running transition curves, assume a center line of temporary tangents in from the true center of the track, in accordance with the column marked "Tangent Offset" on blue prints, and run a simple curve with reference to the temporary tangents. After the simple curve has been adjusted to these temporary tangents in the track the transition curve should be run by ordinates, as shown in the column for "Ordinates" on the same blue print. The temporary point of curve on the simple curve just run being opposite the middle of the transition curve, from it set the point of curve and point of compound curve at the ends of the transition curve. The length of the transition curve for any given simple curve being shown on said blue print. It will not be necessary to put in transition curves on curves flatter than 1°. Stakes should be set every 25′ on transition curves. Iron points should be put at all points of curve, points of transition curve, and at such distances on the simple curves that the curve can afterward be re-run by front sights. They should not be set over 800 feet apart. In running trial and temporary curves it is not necessary to stake with permanent stakes, but a small stake 6″ long and an inch or so in diameter can be whittled out, which can afterward be pulled up, and temporary points can also be put in on the tie. In setting permanent stakes where points come on a tie, tacks should be placed in the tie at the exact point of measurement and line, and the permanent stakes should be set between the ties at the same distance from the rail that the true point comes.

"Keep full notes of all work done, and when practicable use mile post stations."

Raising the outer rail of the curve at the rate of ½ inch in thirty feet should not be made a hard and fast rule, as it frequently is, but should be varied with the speed of the trains. For instance, a train going seventy miles per hour would travel sixty feet while one going thirty-five miles was going thirty feet, and hence would have to raise twice as much in the same time, and thus have a much greater tendency to feel the raise and give a lurch. Here, again, we may have to be governed by local conditions for a 3-degree curve for a speed of fifty miles per hour :

For raise of ¼ inch in 30 feet, length per degree 200 feet, tangent will be set in 7.87 feet.

For raise of ⅜ inch in 30 feet, length per degree 125 feet, tangent will be set in 3.07 feet.

For raise of ½ inch in 30 feet, length per degree 100 feet, tangent will be set in 1.96 feet.

For raise of ¾ inch in 30 feet, length per degree 75 feet, tangent will be set in 1.11 feet.

These figures do not mean that the whole curve would be thrown in that amount, but part of it probably will.

The tables submitted are for lengths 20, 25, 30, 40, 50, 75, 100, 125, 150 and 175 feet per degree of curvature.

These tables are made for offsets, as the corresponding tables for deflections are more cumbersome, and for the work in view on old main track the offsets are as expeditious, if not more so, than deflections. The B. & M. R. R. R. has a set of tables by deflections for sub-chords from fifteen feet to 100 feet long, which are very useful on location and new lines, which are already in print.

The table showing speeds corresponding to the different rates of raise of the outer rail for each of the transition curves submitted will be found useful in assisting to select the transition curve to be used.

In yards, or other places where there is slow speed, the transition curve should not be used, nor for any light curves, say under one degree; but wherever there is high speed, they should be used wherever practicable.

*Mr. John A. Fulton, Chicago, Ill.*—It is probable that a spiral, located by any one of the methods suggested or now in use, will be beneficial in its results and will not differ greatly from a spiral put in by any other method.

The arrangement herein proposed consists in laying off, altogether by offsets, a transition curve, consisting always of six equal chord lengths of curves of uniforn increase in degree.

To illustrate: The transition to a "d" degree curve would consist of six equal lengths of 1/7 d, 2/7 d, 3/7 d, 4/7 d, 5/7 d and 6/7 d degrees, respectively, the constant difference in degree being in all cases one-seventh of the degree of the main curve.

In Fig. 1 it will be taken for granted that the offsets inward from the tangent will be respectively equal to the offsets outward from the main curve, the latter having been set inward the desired distance, EFE.

Fig. 2 is a distorted view of the left-hand half of Fig. 1.

From the geometrical construction of Fig. 2 it is evident that if we let "k" equal the offset AB, then the lower portion of CD will be 2k and the upper portion will be 3k, hence CD equals 5k equals 5 AB.

Similarly the lower portion of EF will be 3k, the middle portion will be 6k, and the upper portion will be 5k. Hence EF equals 14k equals 14AB, and EFE in Fig. 1 equals 28AB.

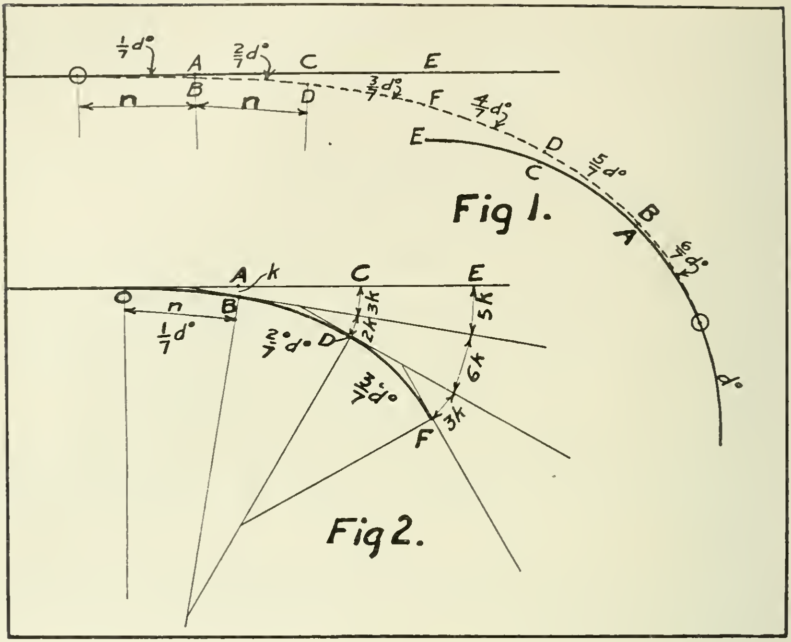


Fig 1.

Fig 2.

The offsets are, therefore, respectively:

| | | |
|---|---|---|
| AB | equals | 1k |
| CD | " | 5k |
| EF | " | 14k |
| EFE | " | 28k |

and may be remembered as the series 1, 5, 14, 28. If we know the value of any one of these offsets, we can readily determine the others.

On page 872 of Mr. Wellington's book there is found a formula first published by him, and probably devised by him, and which has many applications in railroad work.

It reads: " 7/8 $n^2d$ equals offset.

In this formula "n" is the number of one-hundred-foot stations on the tangent, "d" is the degree of the curve, and "offset" is the offset from the tangent to any circular curve, or from any circular curve to any other circular curve having a common point of tangency. It is substantially the external secant or the middle ordinate of a curve; and from this formula we can determine approximately the half length of a reversed curve between parallel tracks when we know the distance the tracks are apart.

Referring to Fig. 2 and using this formula, and assuming the transition curve to pass successively through the points O, B, D and F, we have: AB equals $7/8\ n^2d$. $1/7\ d = 1/8\ n^2d$, hence from what has preceded we have:

AB equals $1/8\ n^2d$
CD " $5/8$ "
EF " $14/8$ "
EFE " $28/8$ " (See Fig. 1)

In this latter formula EFE equals $28/8\ n^2d$, which may be conveniently remembered from the fact that it is just four times the original formula, $7/8\ n^2d$; we have "d" known and constant for any specified curve, and we then have but two unknown quantities, "EFE" and "n," dependent on each other for their value, and assuming a value for either we readily determine that of the other.

If for any reason we desire that the offset EFE shall be a certain definite distance, we assign that value to EFE in the equation and obtain the value of the unit chord length, "n"; or similarly, if we propose to use a certain unit chord length we assign that value to "n" in the equation and obtain the value of the offset, EFE.

For example: Find the offset EFE for a six-degree curve if the unit chord length, "n," is 45 feet—

$$\tfrac{28}{8}\,n^2d = \tfrac{28}{8}\left(\tfrac{45}{100}\right)^2 6 = \tfrac{28}{8}\ \tfrac{2025}{10000}\cdot 6 = 4.25 \text{ feet} = \text{EFE}$$

One way to prepare for the transition curve is to offset the entire original curve inward a distance EFE.

Another and more economical way, on a road already built, is to begin at the middle point of the original curve and locate a new curve in each direction, making it slightly sharper than the original curve in order to throw the ends inward. How much sharper to make it is easily and quickly determined from the formula $7/8\ n^2d$.

Still another way, in case the original curve is a very long one, is to compound it into a sharper curve for some distance at each end, leaving the central portion of the curve unchanged.

There is much flexibility about this method of establishing a transition curve—more, perhaps, than is necessary; and it is well to recognize the fact that the entire amount of super-elevation of the outer rail should be acquired on the transition curve.

It is suggested that the minimum length of transition curve be 120 feet, being six unit chords of twenty feet each for a one-degree curve; and that the maximum length of transition curve be 300 feet, or six unit chords of fifty feet each, which would be for a seven-degree curve or any curve sharper than seven degrees.

Making intermediate values proportional to these will require five feet increase in the unit chord length for each additional degree in that of the main curve up to seven degrees.

If we now condense the subject matter as much as possible:

The total offset at the P.C. or P.T. of a curve is $28/8\ n^2d$.

The several offsets are in proportion as 1-5-14-28.

The unit chord length to be used on a one-degree main curve is twenty feet, and should be increased by five feet for each additional degree in the degree of the main curve up to the limit of fifty feet for a seven-degree curve.

On memorizing these items the necessity for a table of values disappears, although such a table computed for all curves of integral and half degrees would be useful.

Values for curves of fractional degree could be readily obtained from such a table by interpolation.

*Mr. Torrance*—I would like to say, in connection with Mr. Bremner's discussion, that it seems to me that almost every point that he has taken up is nearly identical with the methods I have portrayed. The tangent offset which he has given corresponds to the letter "F" of my illustration.

I would take issue with Mr. Bremner in reference to his method of staking out the curve. He stakes it out from the tangent, as I understand him. I have found that it is very easy and much simpler to stake out one-half from the tangent and the other half from the regular curve. As far as the flexibility of the curve is concerned, I think if anyone should go out into the field without any table at all, he will get along just as well if he just has the means at hand to compute the spiral offset. Either one of the methods I have given, or the more complicated methods given in other books, answer for this purpose. The curve is flexible enough so that if it is desired you could use any length—$\frac{1}{2}$ in. to 100 ft. or $\frac{1}{2}$ in. to 300 ft., while by the same means I have suggested using $\frac{1}{2}$ in. to 30 ft. It seems to me that we are speaking about the very same thing, practically, only I would argue that tables are not necessary, and if you get in the habit of using them, it is hard to get along without them.

*Mr. Finley*—Mr. Torrance's paper brought out the fact that, while engineers differ in their methods, other engineers question the utility of the spiral altogether.

*Mr. Bremner*—I would like to say, in regard to the experience we have had with spirals on our road, that I did not think there was any necessity for defending the spiral. We have been spiraling curves for the last ten years as fast as we have relined them, and I have never heard any fault found with them, and everybody has been pleased with the results from spiraling the curves, and I do not think any of these curves have ever been staked over on the old tracks, except in such places where we have made a radical change and have had to reconstruct on account of the bed being soft. I agree with Mr. Torrance that this curve can be staked from the curve itself as well as from the tangent, but cannot agree with him that the use of tables is not a necessity at the present day. Of course their use may not be so necessary with some people as with others, but with the ordinary engineers I think it is a good deal better to have the tables where they can be readily referred to.

*Mr. Torrance*—This last argument, of course, is well taken, but I think an engineer's knowledge should be assumed for the surveying problem. It seems to me that it is almost as simple as it is to stake out a circular curve, and I think the engineering profession will learn that very quickly.

*Mr. F. K. Vial*—About twenty years ago Mr. E. Holbrook gave definite form to the railway transition spiral in which the degree of curve varies directly as its length. His statement of the problem and demonstration of formulæ relating to it are models of clear, concise, mathematical deductions showing the feasibility of the use of the spiral in railway alignment. The mathematics involved, however, is the differental calculus as applied to the sine, cosine, and tangent series. While this method may be the most perfect from a mathematical point of view, the calculus methods are not in common use in ordinary field operations, especially when the more elementary branches of mathematics answer equally as well.

It is unfortunate that most writers on the Holbrook spiral have thought it advisable to follow the Holbrook mathematics verbatim. This gives the formulæ and demonstration the appearance of being difficult, for one cannot follow from equation to equation without a review of calculus, and the result has been that most engineers turn from the general solution of the curve and are content with a single property of the spiral, which locates a few specified points as center, quarter, or eighth points, etc., and these generally by an offset from the tangent or circular curve.

To supply the needs of the instrument man numerous spirals have been calculated, with special methods for locating them on the ground. These give no aid in getting at the essence of the spiral, since they are special solutions of certain fixed spirals and must be applied by fixed rules, leaving no discretion to the instrument man to suit the infinite variety of conditions met with in practice. Many of the more important railroads have special tables for use on their systems, and aside from these there are many methods with tables published in book form. Among the latter may be mentioned Searles, Torrey, Fox, Crandall, Howard, Talbot, Nagle, Frost, Godwin, Allen and others, all of which are more or less valuable. In each case the statement is made that the tables, as developed, apply to a sufficient number of spirals to meet all cases likely to arise in practice. This the writer has not found to be true, for one often finds that a spiral of different rate from any given in the tables he may have at hand is the one that should be used under the conditions confronting him; or the method of application may not be compatible with the conditions found in a special case.

A spiral may occur in a cut and the P. C. C. cannot be seen from the P. S., (this case eliminates those deflection tables which apply to the point of spiral only), or the spiral may pass over a steep bank so that one end cannot be seen from the other, and the offset method becomes crude and out of keeping with the balance of the field work.

Trestles at or near the P. C. or P. T. of a curve should often have a spiral alignment, and the center of each bent should be located, and a right angle turned to the curve at each point to determine the line for the piles. This is a good practical case to test the ability of the instrument man to adopt the spiral to any condition he may meet. After having had several of these spiral problems to solve and noting wherein the published tables failed to give entire satisfaction, the writer attempted a general solution of the spiral by methods entirely analogous to those familiar to every instrument man who understands the first principles of the circular curve. Since the writer has not seen this method of reasoning used in any discussion of the spiral, it will be given in detail.

The Holbrook spiral is defined as one in which the degree of curve increases directly as the distance from the point of spiral. Thus, if the degree of curve is 1° at station 1, it will be 2° at station 2, and 3° at station 3, etc.

The rate of increase in curvature is an important factor, and will be used as analogous to the degree of curve in circular curves in calculating deflections. Thus, a 1°, 2° or 3° spiral is one in which the degree of curve is 1°, 2° or 3° respectively at 100 feet from the P. S.

The following nomenclature will be used:

$L$ = length of spiral in stations of 100 ft.
$C$ = length of uniform chords, in decimals of a full station of 100 ft. = distance between stakes.
$n$ = number of chords.
$r$ = rate of transition for any chord length, or the rate at which the central angle of successive equal chords increases.
$a$ = rate of transition for 100 ft. = degree of curve at 100 ft. from point of spiral.
$i$ = instrument point, or the distance of instrument point from P. S. in terms of $n$.

D = degree of curve at any point.
R = radius of circular curve.
d = deflection from tangent at any point.
c = angle between any two chords intersecting at instrument point.
$\triangle$ = total central angle of spiral.
I = total central angle of the whole curve, including spirals.
O = distance between parallel tangents.
X and Y = coördinates for any point.
t = correction to be subtracted from $\frac{1}{2}$L to give distance from P. S. to P. C.
T = distance from P. I. to P. S.
P. S. = point of spiral.
P. C. = point of circular curve on parallel tangent.
P.C.C. = point where spiral joins circular curve.
P. I. = point of intersection of tangents.

## *Working Formulæ.*

$$\triangle = \frac{n^2}{2}r = \frac{L^2}{2}a \tag{1}$$

$$D = \frac{rn}{C} = aL \tag{2}$$

$$r = C^2a \tag{3}$$

$$a = \frac{r}{C^2} = \frac{D}{L} \tag{4}$$

$$d = \frac{1}{6}r\,(n-i)\,(n+2i) = \frac{1}{6}a\,(L-i)\,(L+2i) \tag{5}$$

$$d\ (\text{from P. S. only}) = \frac{1}{6}rn^2 = \frac{1}{6}aL^2 \tag{6}$$

$$c = \frac{1}{6}r\,(n-n')\,(n+n'+i) = \frac{1}{6}a\,(L-L')\,L\times L'i) \tag{7}$$

$$X = \text{approx. } .291\,aL^3 \tag{8}$$

$$O = X-R \text{ vers. } \triangle = \text{approx. } \frac{1}{4}X = .0727\,aL^3 \tag{9}$$

$$T = (R+O)\text{ tang. } \tfrac{1}{2}I + (\tfrac{1}{2}L-t) \tag{10}$$

Demonstrations of above formulæ are given below.

### *To Find the Total Central Angle of Spiral.*

In Fig. 1, let the rate with which the central angle increases be called the rate of transition, and its amount be represented by r; then, if the first chord is made to subtend an angle at the center of $\frac{1}{2}$r, and each successive equal chord subtends an angle greater than the preceding by r, the degree of curve at each point will satisfy the definition, and the successive chord angles are $\frac{1}{2}$r, 1$\frac{1}{2}$r, 2$\frac{1}{2}$r —— (n−$\frac{1}{2}$)r. The total central angle for any given number of chords is the sum of this arithmetical series, or

$$\triangle = \tfrac{1}{2}r + (n-\tfrac{1}{2})r\;n = \frac{n^2}{2}r \tag{1}$$

If the chord length be made one foot, then $n = 100L$, and

$$\triangle = \frac{L^2}{2} a \qquad (1)$$

The degree of curve by definition is,

$D = aL = \frac{rn}{C}$ . r for different chord lengths, varies as the square of the lengths; then (2)

$$r = C^2a, \text{ and, } a = \frac{r}{C^2} \qquad (3)$$

To show that deflections from the point of spiral $= \frac{1}{3} \triangle$

In Fig. 1 it will be seen that the spiral could be located as a multiform compound curve, by moving the instrument to each chord point, locating one point in advance at a time, the angles turned at each point, the back sight remaining at station 0, are shown in Fig. 1 on the inner row, thus the angles from station 1 to locate station 2 would be $\frac{1}{4}$r from back sight to tangent at station 1, and $\frac{3}{4}$r from this tangent to station 2, or a total of r from the first chord through station 1; the angle between the chords 0-1 and 0-2 would be $\frac{1}{2}$ this amount, since station 1 lies half way between station 0 and station 2.

In each case the angle between the long chords from 0 can be found by a similar proportion, and are shown in the outer angles in Fig. 1. It will be noticed that each successive deflection from 0 becomes $\frac{1}{3}$ the central angle for that arc, except the first, for the reason that it was considered a circular arc. Had we conceived this arc to be made up of a number of arcs compounded, the first deflection would have been $\frac{1}{3}$ the central angle, or $\frac{1}{6}$r, and the deflection to any point becomes $\frac{1}{3}\triangle$ (see *Eng. News*, Sept. 20, 1900, for a somewhat more complete demonstration). Notice that since the successive angles at the center increase by the constant amount r, the successive deflections must increase by $\frac{1}{3}$r, and the deflections to any point from P.S. is the sum or the arithmetical series in which the first item is $\frac{1}{6}$r, the last item is r $\frac{1}{3}$n — $\frac{1}{6}$r, and the common difference is $\frac{1}{3}$r; then

$d = \frac{\frac{1}{3}rn}{2} n = \frac{1}{6}rn^2$, or otherwise, since $d = \frac{1}{3}\triangle$, substituting for $\triangle$,

$$d = \frac{1}{6}rn^2 = \frac{1}{6}aL^2 \qquad (6)$$

In the above we have given no values to the chord lengths; consequently, we may make them as short as we choose until the points of compound become consecutive and the degree of curve changes at every point which conforms to the definition.

### *To Find Deflections from a Tangent at any Point.*

If from any chord point in Fig. 1 we reduce the chord angles in either direction by nr, the remaining angles become $\frac{1}{2}$r, 1$\frac{1}{2}$r, 2$\frac{1}{2}$r

$=(n-\frac{1}{2})r$, which is the same series we had from the beginning of spiral; and the quantity nr for each chord satisfies the condition of a circular curve; *i.e.*, the spiral deflects from a circular curve of the same degree of curve at any point with the same rapidity it does from the initial tangent. Much is made of this feature by

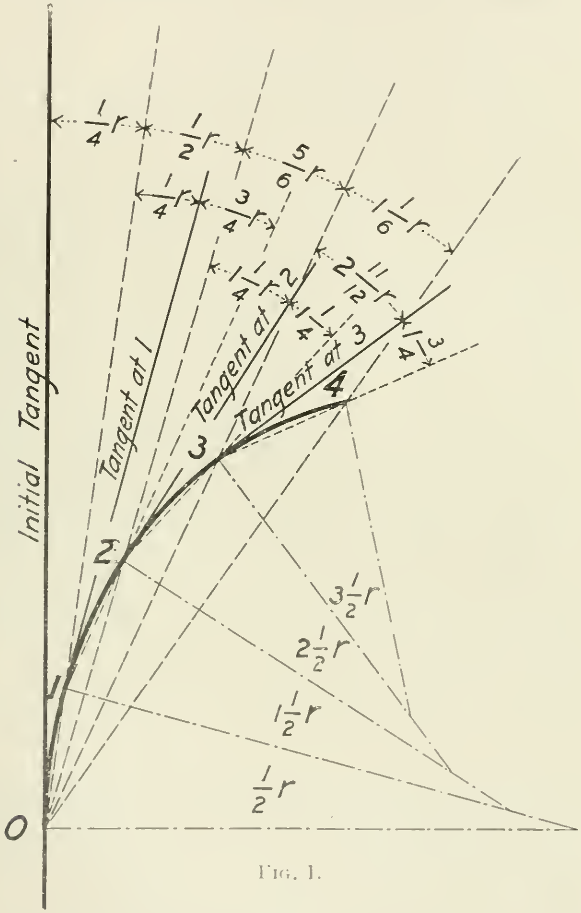


FIG. 1.

many writers, but it is somewhat cumbersome to calculate the deflection in parts and afterwards combine into a whole; while it is correct in theory, it multiplies the chances for error in practice. Thus the deflection from any point can be considered as made up of the deflection for the spiral for an equal distance from the point of spiral, plus or minus the deflection for a circular curve whose central angle is nr per unit of length. The latter part of the deflection then is $\frac{1}{2}rn(n-i)$, which is $\frac{1}{6}rn(n-i)$ greater than for the deflection from P. S. in a spiral of equal central angle (since the circular curve deflection is $\frac{1}{2}\triangle$ and spiral deflection is $\frac{1}{3}\triangle$). The deflection from a tangent at any point is then $\frac{1}{3}$ the central angle of the portion considered (which by summing the arithmetical series is

$\frac{ir + nr}{2}(n-i)$ plus or minus $\frac{1}{6}rn(n-i)$, or

$$d = \tfrac{1}{6}r\,(n-i)\,(n + 2i), \text{ or when } C = 1 \text{ ft.} \qquad (5)$$

$d = \frac{1}{6}a\,(L-i)\,(L + 2i)$, $i$ being in decimals of 100 ft. station.

When $i = 0$, then as before

$$d = \tfrac{1}{6}rn^2 = \tfrac{1}{6}\,aL^2 \qquad (5)$$

Notice that $\frac{1}{6}r\,(n-i)$ is analogous to the deflection for a circular curve, in that it is a rate per unit of length multiplied into the distance covered by the deflection, but for the spiral deflection it is necessary to multiply further by the factor obtained by adding twice the station number of instrument point, and the station number of the point to which the deflection is desired. This is perfectly general wherever the instrument point or the point to which the deflection is desired.

DEFLECTION TABLE.—It thus becomes an easy matter to tabulate from the above formula the quantity $(n-i)\,(n + 2i)$ for various values of n and $i$, which, when taken from the table and multiplied by $\frac{1}{6}r$, which is constant for any given spiral when distance between stakes is decided, will give the desired deflection. See Table I.*

In the table difference columns are given from which the formula as above given may be readily deduced. Note the ease with which the table is constructed since the second differences in vertical, horizontal and diagonal directions are constant.

### *To Determine the Angle Between any Two Chords Intersecting at any Point on the Spiral.*

This angle is the sum or difference, as the case may be, of the angles made by each chord with the given tangent, thus using $i$ as the intersection of the chords and n and n′ as the other extremities of the chords, we have

$$C = \tfrac{1}{6}r\,(n-n')\,(n+n'+i) = \tfrac{1}{6}a\,(L-L')\,(L+n+i) \qquad (7)$$

### *To Find the Co-Ordinates X and Y.*

The most satisfactory method of determining the co-ordinate for any point is by the method of latitudes and departures. For the ordinary range of spirals one table is sufficient. Table II is calculated on a basis of one minute rate of transition for 10 feet of arc.

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*It would be better in many ways to tabulate $\frac{1}{6}$ this amount, the only objection being the introduction of fractions in the table, which is avoided by using full units

TABLE I.

| CHORD POINT n | DEGREE OF CURVE D | CENTRAL ANGLE Δ | INSTRUMENT AT CHORD POINT NO. | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| | | | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. | DEF. |
| 0 | 0 | 0 | 0 $_{1}$ | 2 $_{2}$ | 8 $_{3}$ | 18 $_{4}$ | 32 $_{5}$ | 50 $_{6}$ | 72 $_{7}$ | 98 $_{8}$ | 128 $_{9}$ | 162 $_{10}$ | 200 $_{11}$ | 242 $_{12}$ | 288 $_{13}$ | 338 $_{14}$ | 392 $_{15}$ | 450 $_{16}$ | 512 $_{17}$ | 578 $_{18}$ | 648 $_{19}$ | 732 $_{20}$ | 800 $_{21}$ |
| 1 | $\frac{6}{c}$ | 3 | 1 $_{3}$ | 0 $_{4}$ | 5 $_{5}$ | 14 $_{6}$ | 27 $_{7}$ | 44 $_{8}$ | 65 $_{9}$ | 90 $_{10}$ | 119 $_{11}$ | 152 $_{12}$ | 189 $_{13}$ | 230 $_{14}$ | 275 $_{15}$ | 324 $_{16}$ | 377 $_{17}$ | 434 $_{18}$ | 495 $_{19}$ | 560 $_{20}$ | 629 $_{21}$ | 712 $_{22}$ | 779 $_{23}$ |
| 2 | $\frac{12}{c}$ | 12 | 4 $_{5}$ | 4 $_{6}$ | 0 $_{7}$ | 8 $_{8}$ | 20 $_{9}$ | 36 $_{10}$ | 56 $_{11}$ | 80 $_{12}$ | 108 $_{13}$ | 140 $_{14}$ | 176 $_{13}$ | 216 $_{16}$ | 260 $_{17}$ | 308 $_{18}$ | 360 $_{19}$ | 416 $_{20}$ | 476 $_{21}$ | 540 $_{22}$ | 608 $_{23}$ | 690 $_{24}$ | 756 $_{25}$ |
| 3 | $\frac{18}{c}$ | 27 | 9 $_{7}$ | 10 $_{8}$ | 7 $_{9}$ | 0 $_{10}$ | 11 $_{11}$ | 26 $_{12}$ | 45 $_{13}$ | 68 $_{14}$ | 95 $_{13}$ | 126 $_{16}$ | 161 $_{17}$ | 200 $_{18}$ | 243 $_{19}$ | 290 $_{20}$ | 341 $_{21}$ | 396 $_{22}$ | 455 $_{23}$ | 518 $_{24}$ | 585 $_{25}$ | 666 $_{26}$ | 731 $_{27}$ |
| 4 | $\frac{24}{c}$ | 48 | 16 $_{9}$ | 18 $_{10}$ | 16 $_{11}$ | 10 $_{12}$ | 0 $_{13}$ | 14 $_{14}$ | 32 $_{15}$ | 54 $_{16}$ | 80 $_{17}$ | 110 $_{18}$ | 144 $_{19}$ | 182 $_{20}$ | 224 $_{21}$ | 270 $_{22}$ | 320 $_{23}$ | 374 $_{24}$ | 432 $_{25}$ | 494 $_{26}$ | 560 $_{27}$ | 640 $_{28}$ | 704 $_{29}$ |
| 5 | $\frac{30}{c}$ | 75 | 25 $_{11}$ | 28 $_{12}$ | 27 $_{13}$ | 22 $_{14}$ | 13 $_{15}$ | 0 $_{16}$ | 17 $_{17}$ | 38 $_{18}$ | 63 $_{19}$ | 92 $_{20}$ | 125 $_{21}$ | 162 $_{22}$ | 203 $_{23}$ | 248 $_{24}$ | 297 $_{25}$ | 350 $_{26}$ | 407 $_{27}$ | 468 $_{28}$ | 533 $_{29}$ | 612 $_{30}$ | 675 $_{31}$ |
| 6 | $\frac{36}{c}$ | 108 | 36 $_{13}$ | 40 $_{14}$ | 40 $_{15}$ | 36 $_{16}$ | 28 $_{17}$ | 16 $_{18}$ | 0 $_{19}$ | 20 $_{20}$ | 44 $_{21}$ | 72 $_{22}$ | 104 $_{23}$ | 140 $_{24}$ | 180 $_{25}$ | 224 $_{26}$ | 272 $_{27}$ | 324 $_{28}$ | 380 $_{29}$ | 440 $_{30}$ | 504 $_{31}$ | 582 $_{32}$ | 644 $_{33}$ |
| 7 | $\frac{42}{c}$ | 147 | 49 $_{15}$ | 54 $_{16}$ | 55 $_{17}$ | 52 $_{18}$ | 45 $_{19}$ | 34 $_{20}$ | 19 $_{21}$ | 0 $_{22}$ | 23 $_{23}$ | 50 $_{24}$ | 81 $_{23}$ | 116 $_{26}$ | 155 $_{27}$ | 198 $_{28}$ | 245 $_{29}$ | 296 $_{30}$ | 351 $_{31}$ | 410 $_{32}$ | 473 $_{33}$ | 550 $_{34}$ | 611 $_{35}$ |
| 8 | $\frac{48}{c}$ | 192 | 64 $_{17}$ | 70 $_{18}$ | 72 $_{19}$ | 70 $_{20}$ | 64 $_{21}$ | 54 $_{22}$ | 40 $_{23}$ | 22 $_{24}$ | 0 $_{25}$ | 26 $_{26}$ | 56 $_{27}$ | 90 $_{28}$ | 128 $_{29}$ | 170 $_{30}$ | 216 $_{31}$ | 266 $_{32}$ | 320 $_{33}$ | 378 $_{34}$ | 440 $_{35}$ | 516 $_{36}$ | 576 $_{37}$ |
| 9 | $\frac{54}{c}$ | 243 | 81 $_{19}$ | 88 $_{20}$ | 91 $_{21}$ | 90 $_{22}$ | 85 $_{23}$ | 76 $_{24}$ | 63 $_{25}$ | 46 $_{26}$ | 25 $_{27}$ | 0 $_{28}$ | 29 $_{29}$ | 62 $_{30}$ | 99 $_{31}$ | 140 $_{32}$ | 185 $_{33}$ | 234 $_{34}$ | 287 $_{35}$ | 344 $_{36}$ | 405 $_{37}$ | 480 $_{38}$ | 539 $_{39}$ |
| 10 | $\frac{60}{c}$ | 300 | 100 $_{21}$ | 108 $_{22}$ | 112 $_{23}$ | 112 $_{24}$ | 108 $_{25}$ | 100 $_{26}$ | 88 $_{27}$ | 72 $_{28}$ | 52 $_{29}$ | 28 $_{30}$ | 0 $_{31}$ | 32 $_{32}$ | 68 $_{33}$ | 108 $_{34}$ | 152 $_{35}$ | 200 $_{36}$ | 252 $_{37}$ | 308 $_{38}$ | 368 $_{39}$ | 442 $_{40}$ | 500 $_{41}$ |
| 11 | $\frac{66}{c}$ | 363 | 121 $_{23}$ | 130 $_{24}$ | 135 $_{25}$ | 136 $_{26}$ | 133 $_{27}$ | 126 $_{28}$ | 115 $_{29}$ | 100 $_{30}$ | 81 $_{31}$ | 58 $_{32}$ | 31 $_{33}$ | 0 $_{34}$ | 35 $_{15}$ | 74 $_{36}$ | 117 $_{37}$ | 164 $_{38}$ | 215 $_{39}$ | 270 $_{40}$ | 329 $_{41}$ | 402 $_{42}$ | 459 $_{43}$ |
| 12 | $\frac{72}{c}$ | 432 | 144 $_{25}$ | 154 $_{26}$ | 160 $_{27}$ | 162 $_{28}$ | 160 $_{29}$ | 154 $_{30}$ | 144 $_{31}$ | 130 $_{32}$ | 112 $_{33}$ | 90 $_{34}$ | 64 $_{35}$ | 34 $_{36}$ | 0 $_{37}$ | 38 $_{38}$ | 80 $_{39}$ | 126 $_{40}$ | 176 $_{41}$ | 230 $_{42}$ | 288 $_{43}$ | 360 $_{44}$ | 416 $_{45}$ |
| 13 | $\frac{78}{c}$ | 507 | 169 $_{27}$ | 180 $_{28}$ | 187 $_{29}$ | 190 $_{30}$ | 189 $_{31}$ | 184 $_{32}$ | 175 $_{33}$ | 162 $_{34}$ | 145 $_{35}$ | 124 $_{36}$ | 99 $_{37}$ | 70 $_{38}$ | 37 $_{39}$ | 0 $_{40}$ | 41 $_{41}$ | 86 $_{42}$ | 135 $_{43}$ | 188 $_{44}$ | 245 $_{45}$ | 316 $_{46}$ | 371 $_{47}$ |
| 14 | $\frac{84}{c}$ | 582 | 196 $_{29}$ | 208 $_{30}$ | 216 $_{31}$ | 220 $_{32}$ | 220 $_{33}$ | 216 $_{34}$ | 208 $_{35}$ | 196 $_{36}$ | 180 $_{37}$ | 160 $_{38}$ | 136 $_{39}$ | 108 $_{40}$ | 76 $_{41}$ | 40 $_{42}$ | 0 $_{43}$ | 44 $_{44}$ | 92 $_{45}$ | 144 $_{46}$ | 200 $_{47}$ | 260 $_{48}$ | 324 $_{49}$ |
| 15 | $\frac{90}{c}$ | 675 | 225 $_{31}$ | 238 $_{32}$ | 247 $_{33}$ | 252 $_{34}$ | 253 $_{35}$ | 250 $_{36}$ | 243 $_{37}$ | 232 $_{38}$ | 217 $_{39}$ | 198 $_{40}$ | 175 $_{41}$ | 148 $_{42}$ | 117 $_{43}$ | 82 $_{44}$ | 43 $_{45}$ | 0 $_{46}$ | 47 $_{47}$ | 98 $_{48}$ | 153 $_{49}$ | 212 $_{50}$ | 275 $_{51}$ |
| 16 | $\frac{96}{c}$ | 768 | 256 $_{33}$ | 270 $_{34}$ | 280 $_{35}$ | 286 $_{36}$ | 288 $_{37}$ | 286 $_{38}$ | 280 $_{39}$ | 270 $_{40}$ | 256 $_{41}$ | 238 $_{42}$ | 216 $_{43}$ | 190 $_{44}$ | 160 $_{45}$ | 126 $_{46}$ | 88 $_{47}$ | 46 $_{48}$ | 0 $_{49}$ | 50 $_{50}$ | 104 $_{51}$ | 162 $_{52}$ | 224 $_{53}$ |
| 17 | $\frac{102}{c}$ | 867 | 289 $_{15}$ | 304 $_{36}$ | 315 $_{37}$ | 322 $_{38}$ | 325 $_{39}$ | 324 $_{40}$ | 319 $_{41}$ | 310 $_{42}$ | 297 $_{43}$ | 280 $_{44}$ | 259 $_{45}$ | 234 $_{46}$ | 205 $_{47}$ | 172 $_{48}$ | 135 $_{49}$ | 94 $_{30}$ | 49 $_{51}$ | 0 $_{52}$ | 53 $_{53}$ | 110 $_{54}$ | 171 $_{55}$ |
| 18 | $\frac{108}{c}$ | 972 | 324 $_{37}$ | 340 $_{38}$ | 352 $_{39}$ | 360 $_{40}$ | 364 $_{41}$ | 364 $_{42}$ | 360 $_{43}$ | 352 $_{44}$ | 340 $_{45}$ | 324 $_{46}$ | 304 $_{47}$ | 280 $_{48}$ | 252 $_{49}$ | 220 $_{30}$ | 184 $_{51}$ | 144 $_{52}$ | 100 $_{53}$ | 52 $_{54}$ | 0 $_{55}$ | 56 $_{56}$ | 116 $_{57}$ |
| 19 | $\frac{114}{c}$ | 1083 | 361 $_{39}$ | 378 $_{40}$ | 391 $_{41}$ | 400 $_{42}$ | 405 $_{43}$ | 406 $_{44}$ | 403 $_{45}$ | 396 $_{46}$ | 385 $_{47}$ | 370 $_{48}$ | 351 $_{49}$ | 328 $_{50}$ | 301 $_{51}$ | 270 $_{32}$ | 235 $_{53}$ | 196 $_{54}$ | 153 $_{55}$ | 106 $_{56}$ | 55 $_{57}$ | 0 $_{58}$ | 59 $_{59}$ |
| 20 | $\frac{120}{c}$ | 1200 | 400 | 418 | 432 | 442 | 448 | 450 | 448 | 442 | 432 | 418 | 400 | 378 | 352 | 322 | 288 | 250 | 208 | 162 | 112 | 58 | 0 |

To find the co-ordinate for any point, divide the distance of point from the P. S. by 10, enter the table with this quantity in the column headed "No. of chords," and take the corresponding quantities from the columns headed "Departure" and "Latitude," multiply the "Departure" by the rate of transition for 10 feet, for X, and the "Latitude" by the square of the rate for Y correction, which is the amount to be substracted from the length to give the co-ordinate Y.

The quantity o is found in the same manner as X, and t is found in the same manner as Y.

TABLE II.

r = 1′ in 10 ft.

| CHORD | o | X DEPART. | Y LAT. COR. | t COR. | CHORD | o | X DEPART. | Y LAT. COR. | t COR. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | .0001 | .0005 | .0000 | .0 | 31 | 3.605 | 14.423 | .604 | .1 |
| 2 | .001 | .004 | .0000 | .0 | 32 | 3.964 | 15.861 | .708 | .1 |
| 3 | .003 | .013 | .0000 | .0 | 33 | 4.347 | 17.392 | .826 | .1 |
| 4 | .008 | .031 | .0000 | .0 | 34 | 4.752 | 19.017 | .959 | .2 |
| 5 | .015 | .061 | .0001 | .0 | 35 | 5.184 | 20.739 | 1.109 | .2 |
| 6 | .026 | .105 | .0002 | .0 | 36 | 5.640 | 22.562 | 1.276 | .2 |
| 7 | .042 | .166 | .0004 | .0 | 37 | 6.122 | 24.488 | 1.464 | .2 |
| 8 | .062 | .248 | .0006 | .0 | 38 | 6.630 | 26.519 | 1.672 | .3 |
| 9 | .088 | .353 | .001 | .0 | 39 | 7.165 | 28.658 | 1.904 | .3 |
| 10 | .121 | .485 | .002 | .0 | 40 | 7.729 | 30.908 | 2.160 | .4 |
| 11 | .161 | .645 | .003 | .0 | 41 | 8.321 | 33.272 | 2.443 | .4 |
| 12 | .209 | .838 | .005 | .0 | 42 | 8.942 | 35.750 | 2.775 | .5 |
| 13 | .266 | 1.065 | .008 | .0 | 43 | 9.594 | 38.348 | 3.098 | .5 |
| 14 | .333 | 1.330 | .011 | .0 | 44 | 10.274 | 41.065 | 3.475 | .6 |
| 15 | .409 | 1.636 | .016 | .0 | 45 | 10.986 | 43.906 | 3.887 | .6 |
| 16 | .496 | 1.986 | .022 | .0 | 46 | 11.732 | 46.872 | 4.337 | .7 |
| 17 | .595 | 2.382 | .030 | .0 | 47 | 12.510 | 49.965 | 4.827 | .8 |
| 18 | .707 | 2.827 | .040 | .0 | 48 | 13.318 | 53.188 | 5.361 | .9 |
| 19 | .831 | 3.325 | .052 | .0 | 49 | 14.161 | 56.543 | 5.940 | 1.0 |
| 20 | .969 | 3.878 | .068 | .0 | 50 | 15.040 | 60.032 | 6.569 | 1.1 |
| 21 | 1.122 | 4.489 | .086 | .0 | 51 | 15.954 | 63.657 | 7.249 | 1.2 |
| 22 | 1.290 | 5.160 | .109 | .0 | 52 | 16.900 | 67.420 | 7.984 | 1.3 |
| 23 | 1.474 | 5.896 | .136 | .0 | 53 | 17.886 | 71.322 | 8.776 | 1.5 |
| 24 | 1.675 | 6.699 | .168 | .0 | 54 | 18.905 | 75.366 | 9.631 | 1.6 |
| 25 | 1.893 | 7.571 | .206 | .0 | 55 | 19.958 | 79.553 | 10.549 | 1.8 |
| 26 | 2.128 | 8.515 | .251 | .0 | 56 | 21.062 | 83.885 | 11.536 | 1.9 |
| 27 | 2.383 | 9.535 | .303 | .0 | 57 | 22.291 | 88.363 | 12.595 | 2.1 |
| 28 | 2.658 | 10.633 | .364 | .0 | 58 | 23.365 | 92.988 | 13.729 | 2.3 |
| 29 | 2.953 | 11.811 | .433 | .0 | 59 | 24.577 | 97.763 | 14.943 | 2.5 |
| 30 | 3.267 | 13.074 | .513 | .0 | 60 | 25.828 | 102.688 | 16.239 | 2.7 |

Table II is extended to show that the error in assuming $o = \frac{1}{4} X$, also that the point P. C. is not exactly opposite the center of spiral.

Assuming $o = \frac{1}{4} X$ gives no appreciable error when used in formula 10 to obtain T, but will not answer for offsetting the tangent for long spirals. It is necessary to consider the correction to $\frac{1}{2}$ L in locating the P. S.

In comparing this table with those that have been calculated by the more precise methods, it will be found that the results here given are correct, while many of the others are far from accurate.

To illustrate the use of the tables, take the example given in the paper of Mr. Torrance, stated as follows:

To connect a 3° curve to a tangent using a spiral 300 ft. long, setting stakes at 50 ft. intervals. Since the degree of curve is 3° at 300 ft. from P. S., the rate of spiral is 1° per 100 ft., or a = 1°, and $r50 = .50^2 x 1° = \frac{1}{4}°$ or 15 min. $\frac{1}{6}r$= deflection for 1st stake = 2½ min.

To find . From table I opposite 6 in first column take from column the quantity 108, which multiplied by 2½ min. = 4°, 30 min.

To find X or tangent offset to end of spiral. From table II opposite 30 in X column, we find 13.074, which multiply by .6 (the rate for 10 ft.) gives X = 13.074x.6 =7.84+

O or F $= \frac{1}{4} X = \frac{7.84}{4} =$ 1.96 ft., or from table 3.268x.6=1.96 ft.

P. S. is ½ L or 1.5 stations further from P. I. than where the P. C. would be were no spiral used. Note, that if the spiral were longer a correction would be necessary, but for this case the correction is only .03 and might be disregarded. If the P. S. is located directly from the P. I. the distance is (1910.08+1.96) tangent ½I+149.07 ft. This requires no more labor than the calculation of tangent distance for circular curve. Deflections become,

| INST. AT P. S. | | | | INST. AT P. C. C. | | |
|---|---|---|---|---|---|---|
| Point | Distance from P. S | Deflections from 6 (from Table 1 | Diff. | Deflections (from Table 1 | Diff. | Tan. Offsets. |
| 0 | | 0 | | 72x2½=3°00′ | 17½′ | .061x.6= .04 |
| 1 | +50 | 1x2½=2½′ | 2½′ | 65x2½=2°42½′ | 22½′ | .485x.6= .29 |
| 2 | 1+00 | 4x2½=10′ | 7½′ | 56x2½=2°20′ | 27½′ | 1.636x.6= .98 |
| 3 | 1+50 | 9x2½=22½′ | 12½′ | 45x2½=1°52½′ | 32½′ | 3.878x.6=2.33 |
| 4 | 2+00 | 16x2½≐40′ | 17½′ | 32x2½=1°20′ | 37½′ | 7.571x.6—4.54 |
| 5 | 2+50 | 25x2½=1°2½′ | 22½′ | 17x2½= 42½′ | 42½′ | 13.074x.6=7.84 |
| 6 | 3+00 | 36x2½=1°30′ | 27½′ | 0 | | |

The P. S. is set by direct measurement from P. I. Set the instrument over the P. I. or any other point on the tangent and turn the deflections as given above for Inst. at P. S. until point 6 or the P. C. C. is reached, the instrument is now moved to point 6, with vernier set at 3° backsight on P. S. and turn the deflections as given above for each stake already set as a check.

When O on the vernier is reached, the direction of the tangent at P. C. C. is established for running in the circular curve. In many cases it is easier to add the difference than to multiply by the quantity in the table; the differences increase by $\frac{1}{3}r$ or 5 min. in this case. By substitution in formula (6) any of the above deflections are found; thus, with instrument at 6 the deflection from tangent to P. S. is 2½′ x 6 x 12 = 3°, or with the instrument at point 6 and back sighted on P. S., the angle to be turned to locate point

3 is by formula (7), $2\frac{1}{2}' \times 3 \times 9 = 1^\circ 7\frac{1}{2}'$, as by table $3^\circ - 1^\circ 52\frac{1}{2}' = 1^\circ 7\frac{1}{2}'$.

The method above avoids the use of an offsetted tangent, and the location of P. C. of circular curve also avoids the use of temporary points on tangent or circular curve, which burden the instrument man with a multiplication of parts.

It is sometimes argued that the circular curve must be located from the P. C. to avoid short back sights; but this can seldom apply, since the variation in setting the vernier of one minute makes an offset of one inch in 300 feet; hence the accuracy in taking the back sight is far within the accuracy possible in turning the deflections. If the spiral were only 100 feet long and the circular curve were very long, an error might be chargeable to a short back sight; but even in this case careful work will give accurate results. A more serious case is, that often the P. S. is not properly located by omitting the "t" correction. In this case it is better to use the offset method, which always checks.

The monuments suggested by Mr. Torrance are those ordinarily used, except that the post opposite P. S. should have the rate of spiral marked on the side opposite EO. In the example given it would be marked a–1°, corresponding exactly to the post at P.C.C. on which is marked the full elevation and degree of curve.

In relining curves in perhaps the majority of cases it is not practicable to run the tangents to an intersection on account of the position of the P. I. being such that it cannot be seen from the track or its elevation in respect to the embankment or cuts, makes the chaining inaccurate. A common practice is to retrace the curve by using long chords and calculating the P. I. by latitudes and departures. Several centers are located which can be compared with the new position of the curve. This is the most accurate method to use on long curves.

### *Length of Spiral.*

The rule given by Mr. Torrance for determining the length of spiral is probably in more general use than any other, yet it does not seem to be entirely consistent on account of the omission of the element of speed, which is a most important factor in determining the amount of superelevation. Thus, for a given superelevation of six inches, the rule calls for a spiral 360 ft. long. This would occur on a 2° 30′ curve for a velocity of 60 miles per hour, or on a 10° curve at 30 miles per hour. In the first case the spiral is passed over in four seconds; in the latter in eight seconds; or in the first case the rate of change in superelevation is 1½ inches per second, and the latter ¾ in. per second. It would seem to be more consistent to make the rate of change in superelevation per unit of time constant, then the length of spiral for a given superelevation would vary as the speed, and since the superelevation on a given curve varies as the square of the speed, the length of spiral for a given curve will vary as the cube of the velocity where the required superelevation is not more than the maximum allowed. There is one element not considered, that is the rapidity in change of direction, but this is not important in curves below 12 degrees.

The following rates for varying velocities give good results:

80 miles per hour a = ½° for 2° curves or less.
60 “ “ “ a = 1° “ 3° “ “
40 “ “ “ a = 2° “ 6° “ “
30 “ “ “ a = 3° “ 10° “ “
25 “ “ “ a = 5° “ 12° “ “
20 “ “ “ a = 8° “ 16° “ “

Note that the lighter curves require the longest spirals. Where there are limiting circumstances, spirals much shorter than the above may be used and yet materially assist the good riding quality of the curve.

In conclusion, the following advantages in the above spiral methods may be mentioned:

1. The simplicity in demonstration gives the instrument man a clear idea of the curve, and shows how each quantity is made up.

2. The tables are short, perfectly flexible, and can be worked up in various forms to suit individual opinions.

3. The table of deflections can be pasted into any field book, and is so simple that it may be reproduced in the field in a few minutes in case no table is at hand, making it unnecessary to carry a book relating to spirals only.

4. The instrument may be moved as many times as desired, and the spiral can be run in either direction.

5. Any unit of length and any rate of transition may be chosen. This is essential in locating centers for trestle bents.

6. The table for X, Y, o and t is general for the ordinary lengths of spirals.

When the maximum degree of curve is small, and only a few rates of spirals are used, of course special tables for those rates are convenient. The tables and methods herein given are accurate, and special tables can quickly be made from them.

## CLOSURE.

*W. M. Torrance* Mr. Morgan, in his letter, contends that the first "salient point" given in my paper needs further proof in both theory and practice.

I do not believe that it is in any railway engineer's experience that spiraling, well done, has not improved the riding of trains, and it is certain that in many cases, like the one given by Mr. Beahan in his letter, spiraling has done what no other means could do toward the desired perfection in smooth riding.

The American Railway Engineering and Maintenance of Way Association has declared in favor of spiraling railroad curves, which should be considered significant, as the majority of the members of that association are practical engineers in charge of maintenance, and who have had curves, both spiraled and unspiraled, to maintain.

Different roads vary a great deal in their practice as to length of run-off. With the transition spiral it is possible to use any length for any degree. Notes can be made very simple by taking merely the usual notes as for any simple curve and in addition only the spiral offset ("F" of my paper) and length ("L" of my paper) of spiral being recorded at each end of the curve.

In the rough part of the road I would not attempt to adhere to any length of spiral, but would only try to come as close to desired length as possible.

I do not believe that many will agree with Mr. Haynes that the length of spiral should be longer for the smaller degree of curve.

Mr. Beahan gives an example of the good results obtained by spiraling one curve on the Lehigh Valley R. R. It might be added that one remedy for improving the track at this point, which had been seriously contemplated, was to change the line to lighter curvature on new roadbed at expense of perhaps $1,500. This expense was avoided by spiraling the curve in its old position.

Mr. Talbot deprecates the method used in my paper for obtaining my formulæ, etc. I did not intend to have it understood that I based the properties given entirely on the approximation that, within the limits mentioned, the sine was proportional to the angle. As Mr. Talbot has stated, the formulæ given are practically correct, any error being easily negligible. It was with a full knowledge that the errors mentioned by Mr. Talbot are compensating that the formulæ mentioned were given. In the case of the formula for spiral offset $F = \frac{L}{6} \text{ sine } (\frac{L}{400} D)$ the value for "F" obtained for any spiral within the limits mentioned varies an almost immeasurable quantity from values obtained by the much more tedious but perfectly correct method given by Mr. Holbrook, Prof. Crandall or Prof. Talbot.

The whole question of spiraling or easement of curves resolves itself into two parts: 1st, Do we want our curves spiraled? and, 2nd, What method shall be adopted for using spirals if we decide to use them?

Taking up the second question first, as Mr. Schenck does, I would say in the first place, that that method for spiraling or easement which, being correct, can be shown to be the simplest, and most flexible for the varying conditions to be encountered, should be the method adopted.

If Hood's method of curve easements be adopted by the engineer, as Mr. Schenck would adopt it, if any, and our problem should be that of spiraling the curve illustrated in Fig. 5 of my paper, it would be quite impossible to make any simple calculations to determine a spiraled curve such as is shown in the upper half of the figure, or, at any rate, I cannot see how any such calculations are to be made. I should like to ask Mr. Schenck how he would do this.

Of course Hood's method would be available for spiraling this curve in the manner shown in the lower half of the figure. Spiraling in this manner would, however, be very expensive and the track would be hard to maintain for a long time.

The trouble is, that Hood gives no simple relation between the length of easement, degree of curve and spiral offset such as is necessary for the calculations required in spiraling curves on old track in an inexpensive manner.

On new construction Hood's tables can be used all right for the curves tabulated, but for no others. He shows five tables giving five different lengths for easements for any particular degree of curve. Thus for a 5 degree curve the lengths available are 600′, 300′, 150′ 60′ and 30′.

What Hood, Beahan, Torrey and Searles have done, in getting out tables of easements, is not really spiraling, but successive compounding at the end of the curve, each finite part being, as Mr. Schenck says, a circular curve.

Holbrook was probably the first to reduce curve easements to a proper scientific basis. He did this by adopting the infinitessimal as his unit of length instead of using the 50-foot, 30-foot, 15-foot or 10-foot chord lengths of Beahan's, Torrey's, Hood's or Searle's systems, and then getting his functions by use of the calculus.

By doing this Holbrook paved the way for the other works of note on the spiral such as Prof. Talbot's or Prof. Crandall's, which really differ none from Holbrook's except that they are more complete.

My own effort, in the paper as presented, has been to pick out the main facts from Holbrook's (or Crandall's or Talbot's) theory and present them without the tedious calculus, in such a way as to be easily understood and applied on construction or maintenance work for any length of spiral and for any degree, integral or otherwise, liable to occur in steam railroad practice.

I would not be hampered with any special spiral tables in the field at all, unless by one such as given with my paper for spiral offsets for variant lengths of spiral and variant degrees of curve. The practical, time-saving surveying party will find the method of setting stakes by offsets as shown in Fig. No. 2 of my paper much better than to use deflections as shown in Fig. No. 3, and after finding the spiral offset "F" by any of the simple methods given, this is very easy. .

Taking up the first question propounded, viz.: Shall curves be spiraled at all?

Mr. Schenck speaks of an investment as a necessary adjunct to the spiraling. In my paper I stated that the cost of construction of a new road would be the same whether the curves be spiraled or not. This statement is made on the theory that the cost is made up of the amount of grading, length of track, at so much a mile, surveys and inspection, bridges on the line, etc. Not one of these items need be more because the curves are spiraled, and only one, that of surveys, could possibly be more, and that only on the supposition that the surveying party does not know how to put in the spirals.

From my own experience I can say that on maintenance work curves can be spiraled for next to nothing. The engineer can get his stakes set, and the trackmen can line to them when putting in new ties or when they are lining up the curve, which lining they must do anyway. This is on the supposition that the curve with spirals as adopted will throw the track but little, as, for example, cases like upper half of Fig. No. 5 or lower half of Fig. No. 7 of my paper, which are typical cases.

If ballasting is being done the cost will be almost absolutely nothing, for in raising the track for the ballast it gets out of line and must be thrown more or less anyway, and the chances are good that no more throw would be required to spiral it than to throw to an unspiraled curve.

Answering the arguments of the antagonist to spirals I would say:

1st. Mr. Schenck states that spirals do not aid in a horizontal direction. There is certainly some use for spirals in this connection, the spiral acting to get the trucks of the train into the habit gradually of the necessary twisting which they must do while on the curve. Also in the case of an unspiraled curve the wheels will from gravity move over close against the inner rail as soon as they get on the superelevation runoff, part of which, at any rate, is on the tangent. As soon as the curve is encountered the wheels will continue for the moment in a straight line and a lurching motion from rail to rail will result. This happens because the gauge of the track is somewhat greater than the gauge of the wheels.

In the case of the spiraled curve the centrifugal force will begin to act at the same point that superelevation begins, and the outer wheel flange will find its proper place against the outer rail at once and remain in that position all the way around the curve.

2nd. Lateral elevation, Mr. Wellington tells us, should depend on the quantity $V^2 D$ where V represents speed or velocity and D the degree of curvature. This being the case, any curve, whether spiraled or not, has lateral elevation put into it according to this quantity, $V^2 D$, for the traffic which it is desired to favor, which is usually the high speed traffic. Experience has taught that the run-off of this lateral elevation should be comparatively short from 40 to 60 feet per inch- and the runoffs must be made whether the curve is spiraled or not.

Mr. Schenck's arguments about misfit for various speeds different from that speed for which the curve was given lateral elevation, apply to any curve having lateral elevation, whether spiraled or not. His statement relative to the fact that many spiral systems are based on a fixed amount of lateral elevation per degree does not apply to my paper, in which it is specifically stated and shown that the utmost latitude is available for choosing the length of spiral for any degree of curve.

I think Mr. Schenck is mistaken about his example of a 4-degree curve with 6¾ inches superelevation, inasmuch as a disagreeable lurch of a passenger train going slowly is impossible; and further, the criticism given by him applies solely to the excessive superelevation, and is entirely independent of the question of spirals.

Mr. Schenck makes several statements relative to the ability of any person to determine the condition (spiraled or unspiraled) of a piece of track. There are few curves that have not been "eased off" to some extent by the trackmen, whether they have had stakes for it or not. It may be that this fact has helped Mr. Schenck in drawing these conclusions.

As an example of good results of spiraling, I will give some facts concerning the work done on the C., C., C. & St. L. Ry. Just east of Sidney, Ohio, are a number of curves of about 3° or 4° curvature. These are quite close to one another and were unspiraled. West-bound trains approaching Sidney on the down grade had to reduce speed greatly, or the ride was very unpleasant for the occupants of the train.

Spiraling these curves greatly improved this piece of track for the riding of the high speed trains and the necessity of reduction of speed was done away with.

It cost next to nothing to do the work, the stakes having been set for center line of spiraled curve during the winter, so that the trackmen had them to go by during the regular spring lining up of the track, and the amount of the throw being small in all cases.

On the whole Indianapolis division of the C., C., C. & St. L. Ry. the cost of maintenance of track was actually less during the years when the curves were being spiraled than in the years preceding, and the results in better riding exceeded expectations.

As a general answer to Mr. Schenck, therefore, I would present that:

Results have shown that where proper methods have been used in spiraling, spirals have been a success, not only not necessarily requiring an extra expenditure, but in some cases actually saving money, both by making better schedules for fast trains possible and by saving in labor of maintenance.

Mr. Fulton's method for easement of curves is deserving of more than passing notice, being a very ingenious method, giving as it does a simple relation between the length of easement, degree of curve and spiral offset.

If, instead of calling the length of easement 6 n (3 n on each side of middle point F) he should call its length 7 n ($3\frac{1}{2}$ n on each side of middle point F), making the points on the tangent and curve thus found the ends of the superelevation runoff, his functions would correspond almost exactly with those for the true transition spiral.

Thus, in the case given by Mr. Fulton for a 6 degree curve with unit chord length n = 45 feet, he finds a spiral offset "EF E" = 4.25 feet, which is almost exactly the correct offset for a true transition spiral of (7 x 45 =) 315 feet length for 6 degree curve. Also the intermediate offsets given correspond closely to the proper offsets for the points $\frac{3}{14}$ and $\frac{5}{14}$ of distance from initial end of spiral 315 feet long, though they vary considerably from the proper offsets for points $\frac{1}{6}$ and $\frac{2}{6}$ of distance from initial end of true transition spiral of length (6 x 45 =) 270 feet.

With this correction Mr. Fulton's method would be nearly as good as any in use for laying out easements, and much easier applied than many. In practice the easement could be staked out precisely as Mr. Fulton suggests, and the posts for marking the ends of the superelevation runoff could then be set at a distance $3\frac{1}{2}$ n either side of the middle point F.

Is is obvious that it is necessary to add this extra one-half unit chord length "n" at each end of the six chord lengths given by Mr. Fulton, when we consider that there is still an easement required between the tangent and the curve of $\frac{1}{7}d^\circ$, and also between the curve of $\frac{6}{7}d^\circ$ and the curve of $d^\circ$, each of which, to be in same ratio of change as the rest of the easement, will extend one-half the chord length "n" in each direction from points where Mr. Fulton left it.

It is just as easy, however, to use the true transition curve for a basis instead of any such method as given by Mr. Fulton. The spiral offset is easily determined (as, for example, by formula—spiral offset $F = \frac{L}{6}$ sine $(\frac{L}{400} D)$, and knowing that the offsets are proportional to cubes of distances from initial point they can be easily determined, the offset for the full length of the spiral being four times the spiral offset, "F."

Mr. Vial's method of curve easements, which he has so carefully worked out, is full of good points. It seems, however, that he has partially defeated the very object he started out to attain. The criticism of the Holbrook method of spiraling given by him is that it is so difficult to follow. Neither would the ordinary instrument man desire to follow through the formulæ and demonstrations given for curve easements by Mr. Vial.

The relation for the spiral offset "O" given by him ("F" of my paper), that it is approximately equal to .0727 a $L^3$ (or .0727 $L^2$ D), is accurate enough for all practical cases, and gives a simple relation between the three quantities (spiral offset, length of spiral and degree of curve), which relation is so essential, especially for easy calculation on maintenance work.

It will not often be necessary to use deflections from intermediate points on a spiral. If the work were maintenance work, and the track were in a deep cut, the spiral could be staked out by offsets, as shown in Fig. 2 of my paper, without getting in trouble on account of the line of sight. The case would be rare indeed where a spiral would be so long that it could not all be seen from either end. Such long spirals are not often used. Therefore, the deflections from either end are all that are usually required.

If we have to turn right angles from the spiral at intervals for pile bents, abutments of bridges or any such reason, the simplest way would be to do it with a tape, using the 3-4-5 method for right-angling. The tangent to the spiral at any point thereon can always be accurately obtained, however, by setting over the point with vernier zero on the initial point and turning an angle equal to twice the deflection angle from the initial point to the point in question; that is, ⅔ of the central angle up that point.

Mr. Vial's method of easements corresponds more closely to the true transition spiral than any of the other methods of easements, not spirals, which have been published, in that he makes the successive arcs increase in curvature by the progression ½, 1½, 2½, etc., instead of 1, 2, 3, etc., as Searles, Torrey, Hood and others did in working up their tables.

His table of deflections is, therefore, so near what such a table should be for the true transition spiral that the differences can be easily neglected, and it could therefore be recommended for use in case it is desired to stake out the spirals by deflections, especially if there is a chance that intermediate points will be used as instrument points.

Mr. Vial's plan for choosing lengths of spiral is not the most advisable for ordinary practice, for the reason that the speed of trains cannot well be made to vary so much. For example, a 6° curve and a 2° curve will be in the same ½ mile. The speed will necessarily be the same on both curves. The 6° curve will need more superelevation than the 2°, and hence will need the longer easement.

In the discussion, the methods suggested for spiraling curves on maintenance work (shown in Figures 4 to 9 of my paper) have not been taken up to any extent. The paper was written with an idea of showing how simple the calculations might be made to obtain spirals on maintenance work without throwing the track to any extent. That was the principal object. I had hoped that the discussion would have been to a greater extent along this line, which is, by all odds, the most important on maintenance work.

## CXLIV.

# MECHANICAL FILTRATION.

Robert E. Milligan. M. W. S. E.

*Read February 26, 1902.*

The purification of water by filtration, while properly regarded as a modern development, was known and approved by the ancients. As far back as 440 B. C. Hippocrates suggested boiling or filtering as a means of avoiding disease where the water supply had been contaminated. Bolton's "Ancient Methods of Filtration" describes many curious devices used in remote times.

Frontinius, in describing the Roman water supply, states that "at the seventh mile on the Via Latina, the Marcia, Tepula and Julia are taken into a covered filtering place, where, as breathing again after their course, they deposit mud," and the construction of the ancient Roman "Castella" as an adjunct to the aqueduct shows a plan for sedimentation. That coagulation of water by the use of a salt of alumina has been practiced from time immemorial by the Hindoos is indisputable, and these three, first coagulation, second sedimentation, and third filtration, form the trinity of mechanical filtration as practiced today. The historical antecedents of purification of water by filtration are most interesting, and constitute a temptation few writers and lecturers are able to resist. Because this is a fact and because easy access to all that is worthy of preservation historically has already been set forth ably and concisely, I will not attempt any elaboration of those efforts, but confine myself strictly to mechanical filtration as a modern development and convey to you such facts and information as may cause you to understand the modern filter now so frequently a factor in the work of the water-works engineer.

### DISEASE IN WATER.

No one familiar with the statistics of typhoid fever and the reduction in the death rate of such cities as Lawrence, Mass.; Hamburg, Germany; Quincy, Ill.; Lorain, Ohio, and many other cities, after the installation of filters for the public water supply, can doubt that this dread disease comes from an impure or polluted water supply and that the remedy logically is to purify that supply ere it reaches the consumer. So much has been written concerning this and other diseases supposed to be water borne, that I feel safe in assuming you to be satisfied as to the fact that epidemics of typhoid fever, for example, are directly due and traceable to an impure supply of water, and that no extended argument is necessary on my part to convince you. It has often been alleged that inasmuch as filtration does not remove all of the germs and because the disease germs form a relatively small proportion of the total germs present, it might be that the proportion of germs going through the filter would consist wholly of disease germs, and thus filtration would simply act as a means of selection and in nowise prevent a threatened epidemic. This of course is a ridiculous assumption and it has been proven over and over again that the filter bed is no respecter of germs, but removes its percentage proportion without regard to condition or quality, and much has been adduced to show a more or less equal distribution of germs throughout the water, so that the filter bed accomplishes an equal percentage reduction, and looking at the matter from the standpoint of a community, filtration becomes a safeguard when applied to that community.

Naturally the knowledge and development of bacteriology has shaped the growth and development of filtration until today the accepted test of the modern filter plant depends upon its ability to remove to a greater or lesser degree all bacteria and growths found in the raw applied water. This applies to the removal in a percentage degree of all kinds as a mass, and does not apply particularly to the removal of special groups of bacteria, as I have shown above. The assumptive theory is that safety or immunity from disease is best obtained where the percentage of removal is the greatest. Logically the percentage of removal is the greatest where the number of bacteria per cubic centimeter in the applied water is the highest, and to offset the weakness of percentage it is common to stipulate that at no time shall there be more than 100 bacteria per cubic centimeter in the effluent or filtered water unless 3,000 or more exist in the raw or applied water. In the latter case where 3,000 or more per cubic centimeter do exist, the removal shall not be less than 96 per cent.

## COAGULATION.

Coagulation is so essentially a feature of mechanical filtration that a thorough understanding of the process is important. In fact, it is a distinctive part of mechanical filtration. It may be said where sedimentation is accomplished upon a muddy water by four days' settlement, that the same result may be accomplished by coagulation in four hours. Roughly considered, coagulation is produced by the introduction into water of a soluble chemical salt, capable of disintegrating and becoming insoluble when brought into contact with certain constant constituents of the water itself. *The

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*The following equations explain the chemical reactions technically

(1) Where alum is used.

$K_2Al_2(SO_4)_4 + 3CaCO_3 + 3H_2O = 3CaSO_4 + K_2SO_4 + 3Co_2 + Al_2(OH)_6$.

(2) Where sulphate of alumina is used:

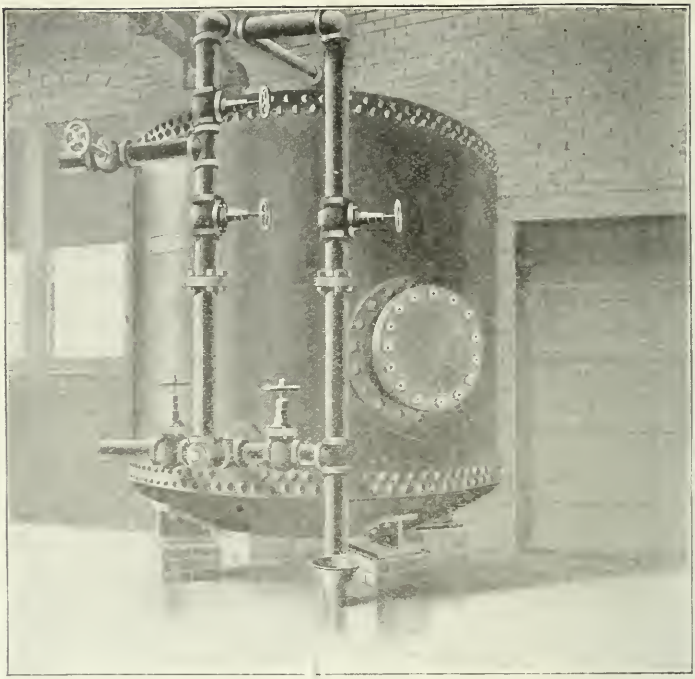
$Al_2(SO_4)_3 + 3CaCo_3 + 3H_2O = 3CaSO_4 + 3CO_2 + Al_2(OH)_6$.

result is the formation of an insoluble gelatinous coagulum of great bulk and relatively greater specific gravity than is possessed by the impurities contained in the water. This coagulum gradually aggregating together, precipitates or subsides throughout the water, enveloping and dragging down such suspended matter and color as it comes into contact with, and after depositing the heaviest portion in the sedimentation tanks, finally in a greater or lesser percentage amount rests upon the filter bed which is interposed between the treated water and the outlet. This coagulum, with its entangled suspended matter resting upon the filter bed, offers to the flowing treated water a closer and more compact surface than would be offered by the sand grains of which the filter bed is composed.

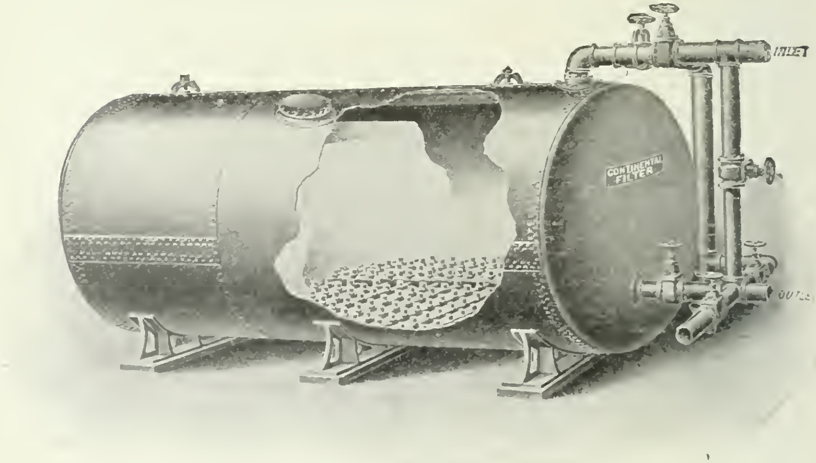
One of the most important differences existing between the mechanical or American filter and its rival or forerunner, the "slow sand" or European filter, consists in the fact that the latter depends upon a natural formation of coagulum by the bacteria themselves; this is called by the Germans "Schmutzdecke." Mechanical filtration provides for the manufacture of its own coagulum through mechanical and chemical processes. Coagulation in this country gradually resolved itself into the employment of the double salt of alumina and potash, commonly called alum, and latterly for commercial reasons been succeeded by the simple sulphate of alumina. A very common example of the work accomplished by a coagulum is that furnished by the practice of clarifying coffee by means of the white of egg. The alum process became widely known, very widely and acrimoniously discussed and finally resulted in the most bitter patent legislation ever conducted in connection with filtration. The patent was issued Feb. 19, 1884, to Isiah Hyatt, of Newark, N. J., and has frequently been called the "Hyatt patent." While this patent was often infringed and proved of no financial benefit to the owner, the result of the litigation was to sustain his ownership and was a very important factor in bringing together the numerous small companies at that time exploiting mechanical filtration under differing forms.

It was also the cause of considerable research by eminent chemists and chemical engineers employed on one side or the other of the controversy, and indirectly caused the development of the present mechanical filter to the very high efficiency now attained.

After considering and investigating the different claims made by the supporters of this or that plan, it became apparent that all there was in mechanical filtration depended upon coagulation, sedimentation and filtration. Investigation of electrical, magnetical, capillary, automatic coagulating and fractional filtration, all of which had and no doubt still have their supporters, tended to prove to the unbiased mind for one reason or another that they were not applicable to the



Vertical Type Pressure Filter Tank.



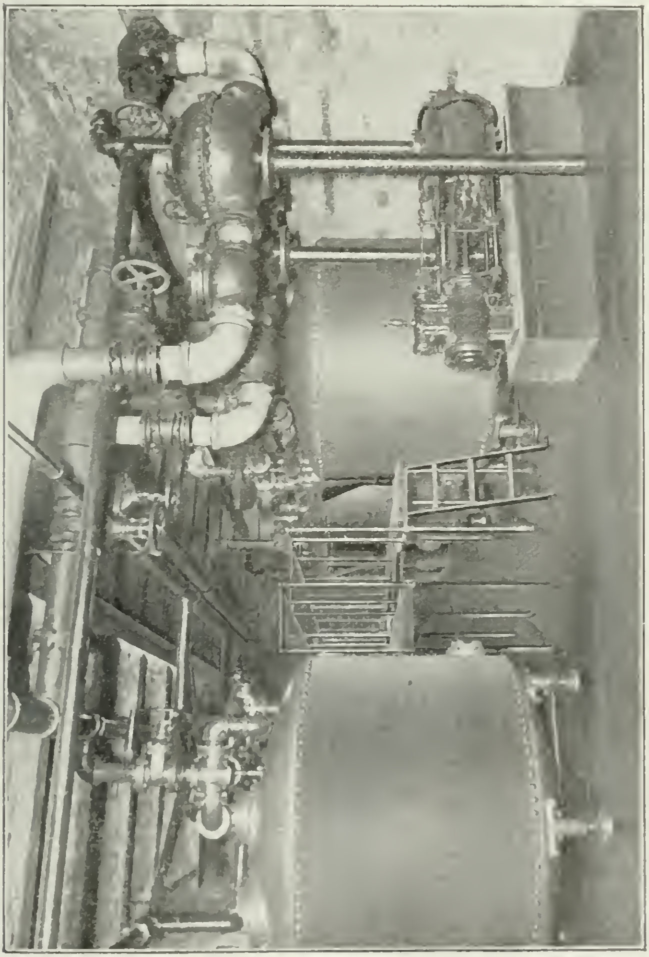
Horizontal Type Pressure Filter Tank.

purification of public water supplies by filtration, and today the mechanical filter, except for its rival, the "slow sand system," stands alone, for the consideration of the water-works engineer.

### PRESSURE FILTERS.

The early exploiters and manufacturers of mechanical filters knew but one general type, the pressure filter, which no doubt is familiar to you.

This class of filter was made in two general forms, the vertical and horizontal (cuts of both are shown here), the vertical type shown in the cut being of the simplest known construction without

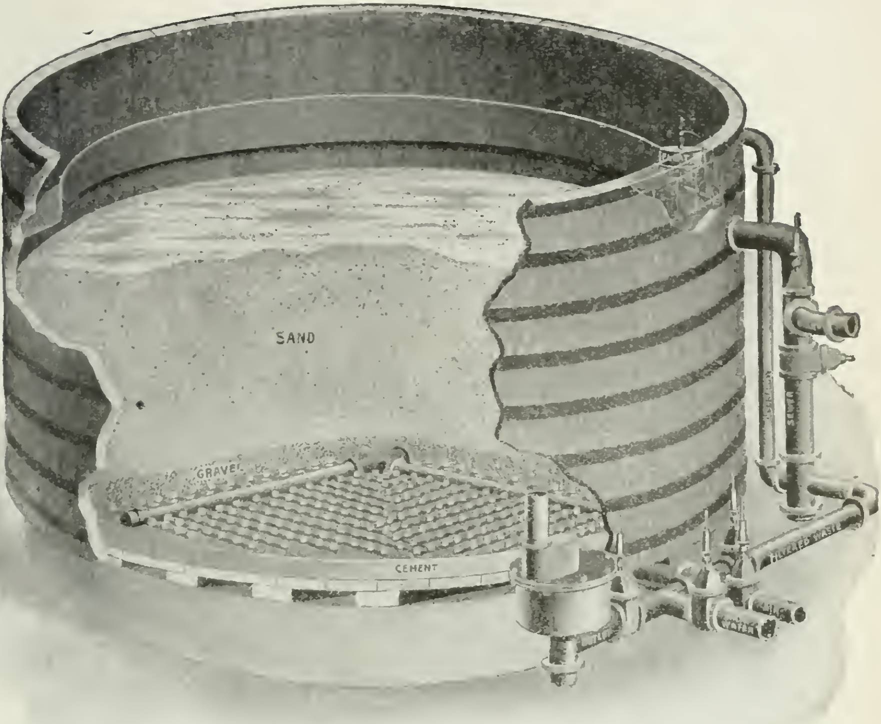


Waldorf-Astoria Hotel—Battery Arrangement of Pressure Filters.

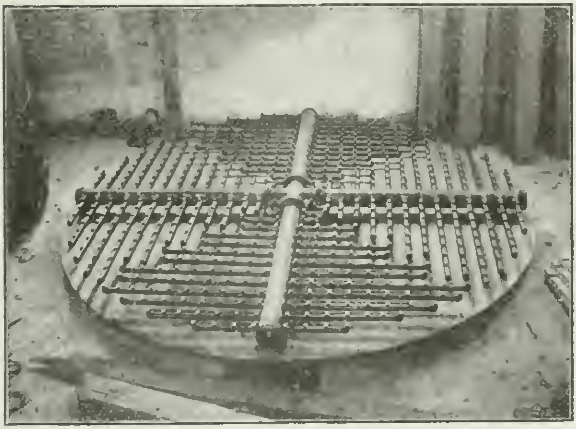
any device to assist in washing—the reverse current of water alone being used. Simple as it is, this particular filter is still at work on Passaic River water and its work is satisfactory. It is true that in some instances pressure filters proved successful and that many are still in use to the satisfaction of the consumer, but it is also true that many failures charged in a general sense to mechanical filtration were due to the installation of pressure filters in places and under circumstances where gravity plants preceded by sedimentation would have proven satisfactory in every sense.

Horizontal Pressure Tank Filters. Plant at Davenport, Iowa.

The compound vertical pressure type, shown on another page, is in use at the Waldorf-Astoria Hotel in New York City. It is, however, a variation from the common pressure filter inasmuch as no coagulum is used in connection with it, two of the tanks constituting one filter in which the first bed is sand and the second hard-burned animal charcoal, the object being the destruction of the yellow color found in the Croton water. The piping and valve arrangements are designed to suit the overhead space. In the foreground may be seen a Knowles air compressor used to assist in the washing process. The air under pressure is forced upward through the filter bed, thus perforating the bed and allowing the wash water easy access to all parts of the bed.



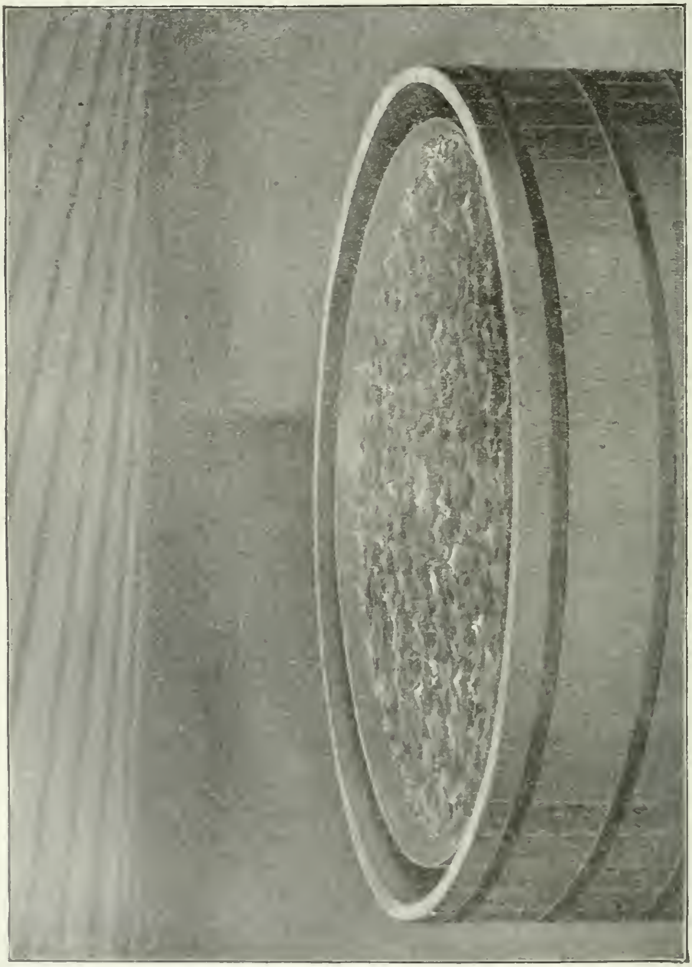
Gravity Filter Tank. 1 Unit, Showing Manifold and Strainers, Sandbed and Overflow Gutter.



Manifold and Bronze Screens, as placed at bottom of Gravity Filter Unit.

Another of the cuts shows the horizontal pressure type filter plant in use for the last ten years by the city of Davenport, Iowa. It is arranged in series, each tank constituting an independent filter, and is known as the "Western type." It has been handling Mississippi River water very successfully since its installation.

During the period of pressure filters the coagulant in solution was fed, as a usual thing, to the applied water through certain devises called coagulant tanks, which devices were covered more or less by patents. Some of these feeds were ingenious, but they were chiefly distinguished by their unreliability to the use for

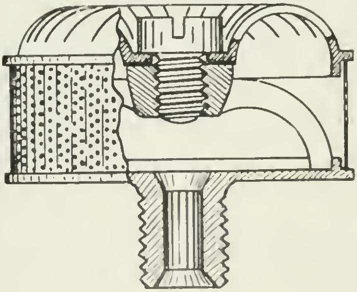


Air and Water Washing Effect, Gravity Filter.

which they were designed. When gravity plants began to succeed their pressure progenitors, other and more exact methods prevailed, and today the common plan is to meter known quantities of a known solution of the chemical by means of independent pumps, while in some instances gravity feeds perform the same work. The gravity system of mechanical filtration, preceded by subsidence, appears to be gradually displacing the pressure type, notwithstanding the fact that two pumpings are necessary in the case of the gravity filter, while the pressure type demands no alteration of the common direct system.

A view of a 15-foot diameter gravity filter is shown here by cut. This is called a "unit," and when subsided water flows to it, it is capable of filtering 500,000 gallons in twenty-four hours. The cut shows the strainer system, the sand layer and the gutter overflow. The shell is of 3-inch dressed cypress lumber. The valve and piping are arranged outside, as may be seen, with controller in the foreground. This filter is arranged in connection with the air-wash system, and is in use in a greater or lesser number of units in many city plants.

Another view of the same 15-foot diameter gravity unit is shown, and the effect of the air and water while the sand bed is undergoing the washing process can be seen. The air is forced from a blower, through a special pipe, to the manifold system, and upwards through the strainers upon which the sand bed rests. Seeking to escape, it perforates the sand bed in every direction and equally, and is followed by the reverse current of water, which, continuing to flow, overflows by way of the gutters through the washout valves to the sewer, carrying with it the accumulated refuse matter dislodged from the surface of the sand bed.



JEWELL BRONZE SCREEN.

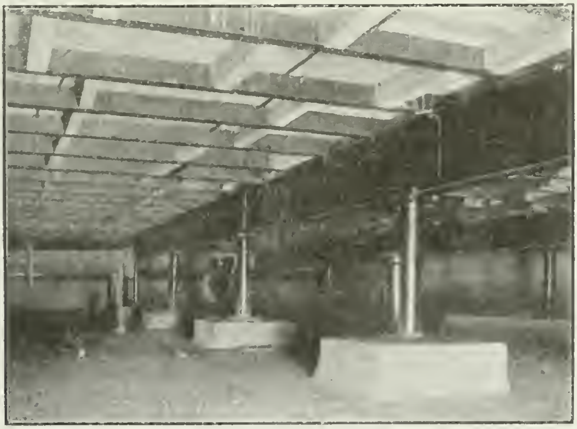
The accompanying cut shows the 3-inch cypress floor, manifold and straining system resting thereon, and may be said to be the beginning of a 15-foot gravity unit. The perforations of the brass strainer cups are drawn to a certain diameter, the total number of perforations being sufficient to equalize the total area of the filter itself. The strainer cups are equi-distant one to the other, and the cut gives an idea of the Jewell slotted strainer itself.

An important adjunct to the modern filter is what is known as the controller. This controller, as the name implies, is intended to regulate the amount of water passing to and from the filter. It therefore controls the rate of flow. It also enlarges the period between washing, as it equalizes the amount of water handled per minute. Frequently, in modern plants, pressure regulators, with dial attached, indicate to the operator the increasing compactness of the bed as the filter continues in use, and notify the operator as to the most economical time to wash the bed.

A complete gravity plant of the mechanical type is arranged as follows: The crude, unfiltered water is lifted by means of low service pumps to settling tanks constructed of wood, steel or masonry. The supply from the pumps, entering at about eighteen inches from the bottom of the settling tanks, has injected into it a measured quantity of solution of sulphate of alumina or sulphite of iron. This coagulant, because of the presence in the water of the carbonates of lime, etc., or, failing that, because of a measured quantity of clear limewater added thereto, decomposes into the insoluble coagulum, in one case hydrate of alumina being formed, in the other case hydrate of iron. The coagulated water after entering the settling tanks gradually rises to the level of the overflow dams, which are placed near the top of the subsiding tanks. The coagulated water in rising to that height gradually leaves behind it in the settling tank the coagulated, suspended impurities to a greater or lesser degree, and these impurities accumulate upon the bottom of the settling tank, while the water, divested to a greater or lesser degree of these impurities, spills or overflows to and upon the filter beds, which are situate exterior to and lower than the settling tanks. The filter tanks consist, as has been shown, of certain units constructed of wood, steel or masonry, very often circular in form, in some cases rectangular. Within these filter tanks, superimposed upon a manifold system of piping connected to a screen system, are the sand beds. The sand employed is sharp river sand, running between 20 and 40 mesh, and the average depth in use is about four feet. These filters must be elevated to a sufficient height to allow for sufficient head above the clear well, that a sufficient amount of water may pass through them, the rate of flow as best practiced being 1¾ gallons per minute per square foot of area. On the other hand, the filters must not be elevated beyond a point below the overflow dam of the subsidence basin or settling tank sufficient to give the necessary head required to carry the subsided water upon the filter bed. The filters are directly piped to the overflow dam of the settling tank.

In the system above described, which is called the continuous system, the water is being pumped continuously, coagulated continuously, and is flowing continuously through the settling tanks to the filters, and is being filtered continuously through the sand layer and strainers, through the manifold system to the clear water well, so long as the plant is in service. From the clear water well high service pumps dispose of the water to the standpipe or reservoir or directly to the consumer.

There are, of course, variations of this system, as, for example, the quiescent subsidence plan, where the subsiding tanks are arranged in two separate units and operated alternately, thus allowing the water on one side to come to a complete state of rest, when by means of floating pipes attached to swivel joints the subsided water is drawn down to and upon the filter bed. The necessity of elevating the settling tanks, the employment of hydraulic valves, larger low service pumps and greater area of subsidence, makes this latter plan more expensive than the preceding one described, and so far as our knowledge of the subject goes no material advantage feems to follow its employment.



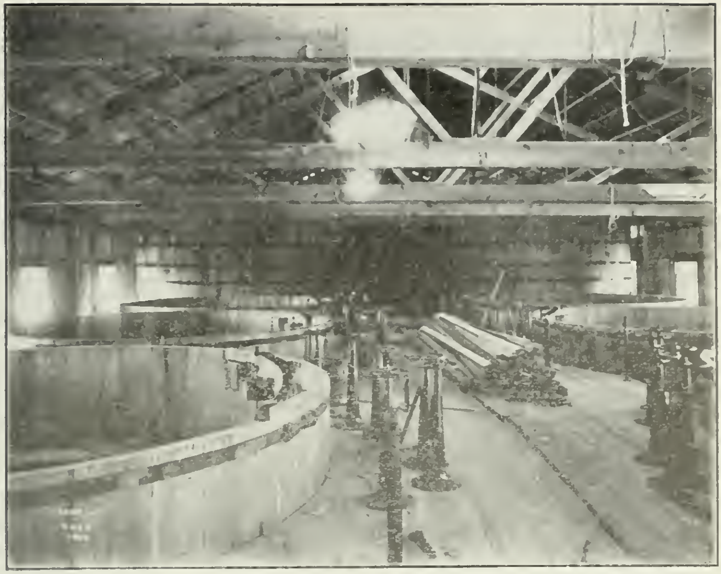
Clear Water Well Filter Plant, Middletown, N. Y.

The sedimentation tanks are usually concreted at the bottom, and the concrete slopes from a foot at the periphrey of the tank to practically nothing at the sewer outlet in the center. This is done to facilitate the discharge of the accumulated, coagulated refuse to the sewer during washing. The necessity of washing the settling tank varies as to the water applied.

Photographs are shown here to make clear the construction of a clear well, as well as to indicate the class of construction often employed in filter plants on our western rivers. The clear well shown is that in use at Middletown, N. Y., while the construction photographs were taken during the building of the plant at Cairo, Ill., on the muddy Ohio. By showing photos of Rensselaer, N. Y., and Norristown, Pa., I wish to indicate to you two dissimilar types of mechanical filters, though the principles underlying the work are, of course, the same. The Rensselaer plant is of the Jewell type, while the Norristown plant offers a good example of the New York type of construction.

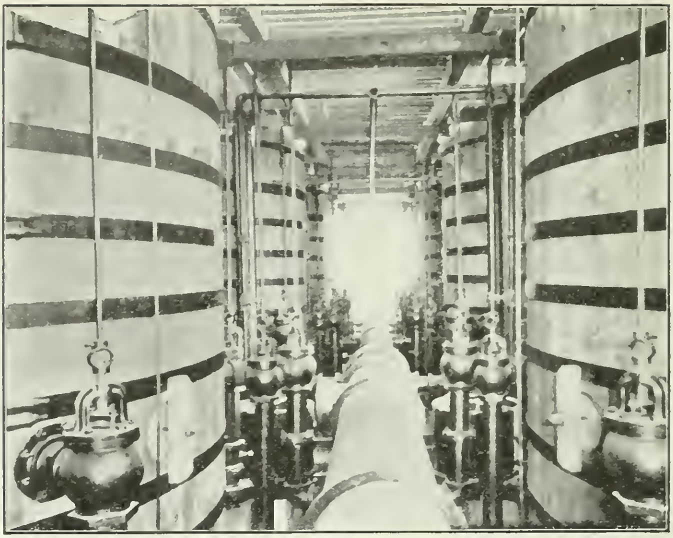
At Cairo, Ill., where a plant of the continuous flow plan is in operation, and handles between 2,000,000 and 3,000,000 gallons of Ohio River water in 24 hours, and where there are four settling tanks 20 feet in height by 25 feet in diameter, it is necessary to wash the settling tanks sometimes as often as once in five days. The time required to wash out is about ten minutes to each tank. The arrangement is such that during the washing operation no part of the plant is out of service, except the unit undergoing washing. During a recent stage of the Ohio River, three feet of solid

Construction of Filter Tanks, Gravity System, Cairo, Ill

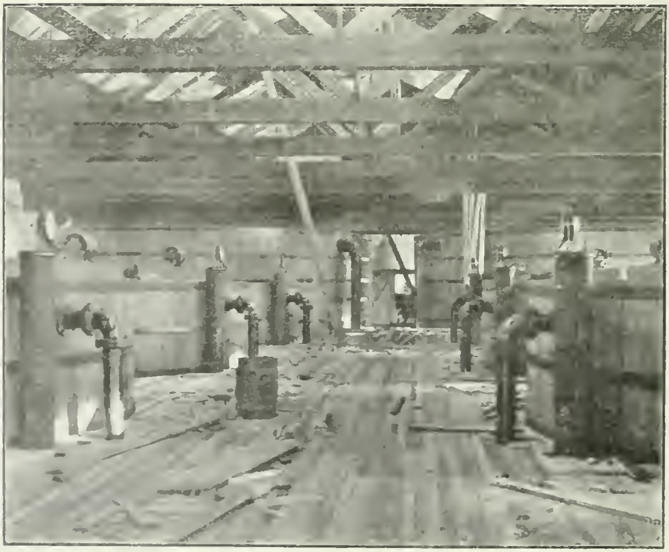


Operating Floor, Filter Plant at Cairo, Ill., Showing Tanks and Operating Valves.

Rensselaer, N. Y. Jewell Type Gravity Filters.



Rensselaer, N. Y. Jewel Type Gravity Filter.



Norristown, Pa. New York Type Gravity Filter.

coagulated refuse had accumulated in the bottom of the settling tanks during the seven days' operation by the writer. At Vincennes, Ind., where the Wabash is the source of supply, and where a plant of the quiescent subsidence plan is installed, less frequent washing is the common rule. Perhaps a fair average for the latter plant would be about once in two weeks. The difference in time is caused by the difference in the quality of supply, though both of these plants are on muddy waters.

A period of two hours' sedimentation of coagulated water is a safe unit on a western river water. Where two hours is employed, the sedimentation tanks may be depended upon to dispose of about 60 per cent of the total suspended matter in the raw water. While the common unit of filtration is a 15-foot diameter filter, which is held to be capable of handling 500,000 gallons of subsided water in twenty-four hours, frequently units of 1,000,000 gallons are employed in plants of over 5,000,000 gallons capacity. The rate of flow under these guarantees is figured on 100 gallons per square foot of area for each hour. Two things are demanded of the modern filter: first, that it shall deliver a certain number of gallons per hour of clear, pure water; second, that it can be readily and perfectly cleansed by mechanical means. The first requirement, as we have seen, depends upon the coagulation and partial subsidence of the water brought to the filter, while the latter requirement depends upon the devices intended to assist in the cleansing of the sand layer.

There are two methods by which mechanical filters may be properly cleansed, viz: the stirring arm or rake device, and the air wash. Where the rake-bar system is in use, the stirring apparatus consists essentially of a heavy cross arm, which swings on a vertical shaft, extending from worm gear on the top to the deflecting elbow. Into this cross arm are keyed three heavy horizontal shafts, which carry the swinging rakes or bars. These bars are secured in swivel collars, which are held between two heavy set collars, having quadrant lugs, which engage the swivel collar when the agitator bars are vertical in the bed. These rakes or bars are arranged to traverse the bed every three inches, thereby reaching all the parts. The worm and worm wheel are combined in one heavy iron casing, making a substantial and perfect running mechanism. As the casing provides for a well of oil in which the worm and wheel dip, both are continually running in oil. The worm shaft is fitted with an end support secured to the cross beam on top of the filter, and is provided with either duplex friction clutches operated with one lever, or tight and loose pulleys with shipper rods. The upper cross beams, on which the worm casing and driving apparatus are mounted, are of hard wood and rigidly fastened to the filter tank by heavy cast iron angle plates or brackets. This appliance, which is a description of the rake bar used in connection with the Jewell filters, is operated by a small engine of six horse power. During the period of washing the filter, the flow of water passes upward through the screen system (the wash valve being open and the filter valve closed) at the rate of about 1,000 gallons per minute for the 15-foot diameter filter. At the same time the engine is started up and the rakes revolve through the sand bed loosened by the water, by which means the accumulated mud and refuse matter is flushed out through the washout pipes to the sewer. On an average it may be said this operation will consume about eight minutes to a filter. Two filters may be washed at the same time, which shortens the period somewhat. When the water flowing to the washout pipe has cleared up to the satisfaction of the operator, the wash and washout valves are closed, the influent and the effluent valves are opened and the filter is again in operation. There is, however, a rewash or "filtered to waste" arrangement of pipes and valves, by means of which the first filtered water may be run to waste until it is satisfactory to the operator.

The air wash operates from rather a different principle, as follows. The air is supplied under pressure from a rotary blower and passes through the discharge pipe into the manifold system, and through the strainers to the filter, where it is introduced evenly under the entire sand bed.

Perfect distribution is a feature of its use, and the pressure exerted at the periphery should be the same as that at the center. The principle involved seems rather to be the perforation of the sand bed than the loosening up effect aimed at by the rake-bar system. At the same time the water following the numerous and equi-distant perforations made by the air under pressure, causes the sand bed to loosen and agitation follows, and so far as results are concerned, the two systems resemble one another, and practical tests have demonstrated that both systems successfully accomplish the desired end.

Inasmuch as no overhead gearing is necessary, where the air wash is in use, and because of the display attending it, I believe the air wash to be the more popular system, while the rake-bar system is probably more economical.

The necessity of washing the filters is to some extent controlled by the amount of suspended matter in the raw waters, at least so far as the procuring of clear water is concerned, but in order that the best average bacterial results may accrue, regular stated periods of washing give the greatest efficiency, and no filter should operate longer than twenty-four hours before being cleansed. The rate of v of water during the period of washing is estimated to be between seven and ten inches per minute, and five gallons per square foot seems to be the amount called for in many contracts, which equals a velocity of eight inches per minute.

Considerable attention is paid to apparatus designed to control the supply to the filter, and controlling the effluent therefrom, it being one of the advantages of the gravity system that control is more readily effected in connection with it than is possible in pressure plants. The first control of value is on the low service pump itself, and a good governor is of great assistance to a filter plant. The water being discharged from the pumps to the settling tanks under control, the subsided water flowing from the settling tanks is controlled at the point where it enters the filter, and this is done by a simple float arrangement —in short, a "butterfly" valve. Lastly, the purified water leaving the filter is controlled by an automatic device as it flows to the clear well.

Many different forms of strainers have been placed in service to convey the wash water to the filter bed, as well as to carry off the filtered water to the clear well. These in the past have been protected by patents, and much has been said as to their relative efficiency. The principle of the Jewell strainer, controlling as it does the pressure just as the water enters it, appears to have established its superiority and is today most generally used.

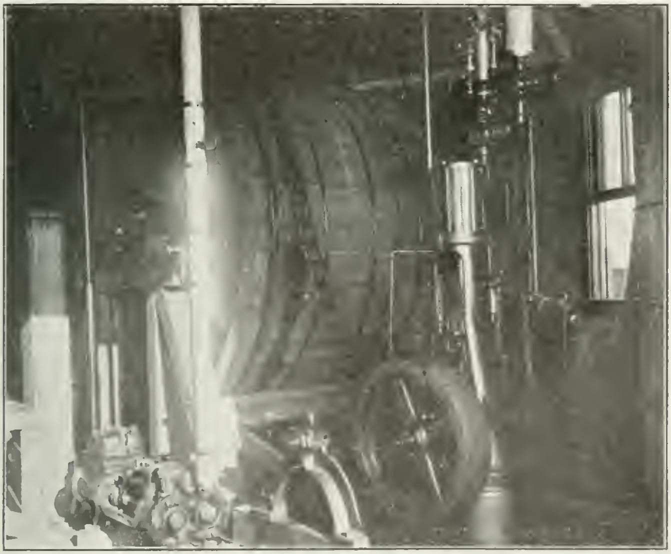
In describing in a general way typical systems of mechanical filtration, I have confined myself to such plants as are best adapted to where the source of supply is drawn from the lakes and rivers, thus avoiding the question of water softening and the removal of iron, which is so frequently a factor in ground waters. I believe these to constitute different subjects and they demand different treatment, although mechanical filtration is a necessary adjunct.

If an imaginary line at the 40th degree of longitude be drawn across the United States, it would be seen in a general way that the water supplies south and west of it are very heavy in suspended matter and chiefly derived from lakes and rivers. To these, then, the interest of the western engineer is more directly drawn, and it is in the handling of these that the general type of purification plants described above prove their greatest value. Here it is that sedimentation, which is cheaper to install than filtration, equalizes the sudden increases and decreases of suspended matter, following the rise and fall of the river supplies. It may be said that sedimentation disposes of between 60 and 70 per cent of the suspended matter and filtration between 30 and 40 per cent, and it must not be forgotten that the removal of suspended matter means also the removal of bacteria, inasmuch as bacteria themselves are in suspension. In the economy, too, the subsiding basins assume prominence, it being cheaper to remove the accumulated refuse matter from a settling basin than from a filter, and the economy is only secondary in importance to the efficiency of the plant, as expressed by the removal of bacteria and the furnishing of clear water.

The annual expense of coagulation when figured as grains to a gallon assumes more formidable proportions when applied to plants handling 2,000,000 gallons and upward in 24 hours, and in considering the installation of mechanical filter plants of large capacity, the consulting engineer is forced to take into consideration the annual expense of coagulation and to regard this expense as an interest charge against hypothetical investment, at the same time bearing in mind the actual necessity of its use in connection with mechanical filtration and that the desideratum devoutly desired is clear, pure water.

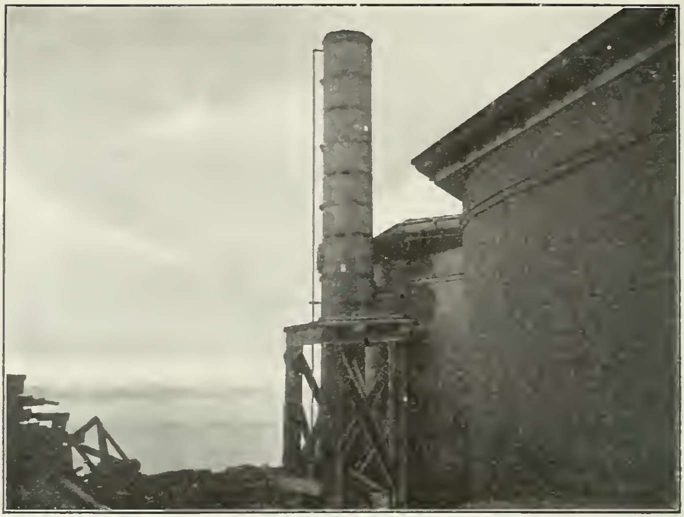
When sulphate of alumina was the sole coagulant at the disposal of manufacturers of mechanical filters, much financial data was used and misused, to prove or dispute the expense or economy of this factor. As a condensed statement it may be said that most plants operating on western waters average about one grain to the gallon throughout the year, which expressed in figures would mean an average charge of about $2.00 for every million gallons of water purified, assuming Philadelphia to be the source of supply of sulphate of alumina.

The growth and development of the iron process has resulted, however, in the use today of a coagulant of equal efficiency and much greater economy than can be expected where sulphate of alumina is employed. The use of iron as a coagulant appears to date back as far as 1857, when Dr. Medlock secured a patent on its use. Spencer in 1867 introduced a material which he called "magnetic carbide," the active agent being iron. In 1871 Bischoff was granted an English patent, and appears to have employed the metal in a porous or spongy condition. Later, the Anderson process became well known as the iron method of purification. Anderson employed iron cylinders revolving on hollow trunnions, the trunnions serving for inlet and outlet pipes. Cast iron borings or punchings were contained within the iron cylinders, and as the cylinders revolved the borings were showered through the water brought into contact with them, a certain amount of the iron being thus held in solution or semi-suspension, and the excess of the iron was kept constantly bright and clean by attrition. The water as it issued from the purifiers (so-called) was exposed to the air as it flowed through a trough, this inducing the precipitation of the iron hydrate, and by subsequent filtration through sand the coagulum thus formed, along with the adhering suspended impurities, was removed. Anderson, whether he knew it or not, seems to have depended upon the carbonic acid native in the water to retain the iron in solution, and subsequent exposure to air to render it insoluble; but unfortunately carbonic acid in water is very variable, indeed. Besides, to get the fullest effect from what carbonic acid did exist, it was necessary to pass all the water to be purified through his cylinders, which, of course, caused them to be of large dimensions and involved great expense, both in first cost of installation and in maintenance, as power was required to cause them to revolve. Nevertheless, this is probably the germ from which the modern and highly successful iron process of today has been evolved. A description of the iron process as it exists today in its greatest development will, I believe, show the resemblance to the Anderson process, as well as point out the very great differences existing between them.



Ferons Wheel or Drum for Generation of Iron Solution, Quincy, Ill

The plant described is in use at Quincy, Ill., the supply being the Mississippi River. About 5,000,000 gallons are being purified daily at a cost of about $1.20 per million gallons. The plant furnishing the iron solution consists of a wooden condenser superimposed above a storage tank also of wood. The storage tank being connected to the revolving wheel or drum, which, constructed of wood, is situated within the building. The fitting from the storage tank consists of a small length of cast iron pipe connecting



Acid Condensing Tower Outside of Iron House, Quincy, Ill.

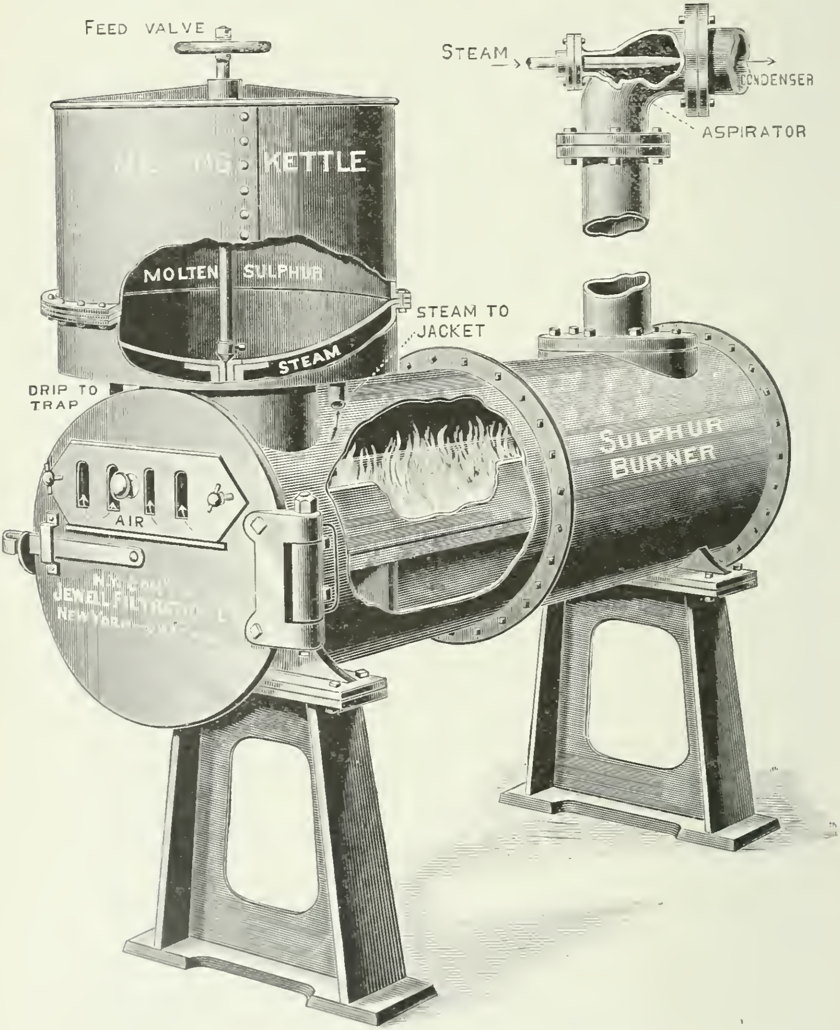
Lime-Water Tank, Quincy, Ill.

to the revolving drum. The union between the axle or trunnion of the revolving drum and the end of the short line of cast iron pipe, through which the acid solution flows to the drum, consists of a pleated piece of pure rubber pipe, which, being accordion-pleated, although revolving, does not buckle, but recovers its equilibrium at every revolution. The acid solution flowing through this rubber connection to the revolving drum comes into contact with cast iron filings and scrap contained within the drum. The drum is revolved at the rate of 4½ revolutions per minute. The internal arrangement of the drum is such that the cleats or projections on the inner wall pick up the iron scrap, and as the drum revolves showers it again and again through the acid solution. The dimensions of the drum are 6 feet in diameter and 4 feet wide inside.

A photographic view shows the outside of the iron house at Quincy, Ill. It shows the condensing tower where the sulphurous acid gas is condensed to sulphurous acid solution by coming into contact with water. The view also shows scrap iron in the foreground. The acid solution as it leaves the condenser is, of course, very weak, being a little more than sour to the taste. Another view gives the interior of the iron house at Quincy, Ill., showing the ferrous wheel or revolving drum, which, when revolving, showers the iron contained within through the acid solution flowing to it from the condenser. The sprocket arrangement may be seen, which, in connection with a small engine, causes the wheel to revolve.

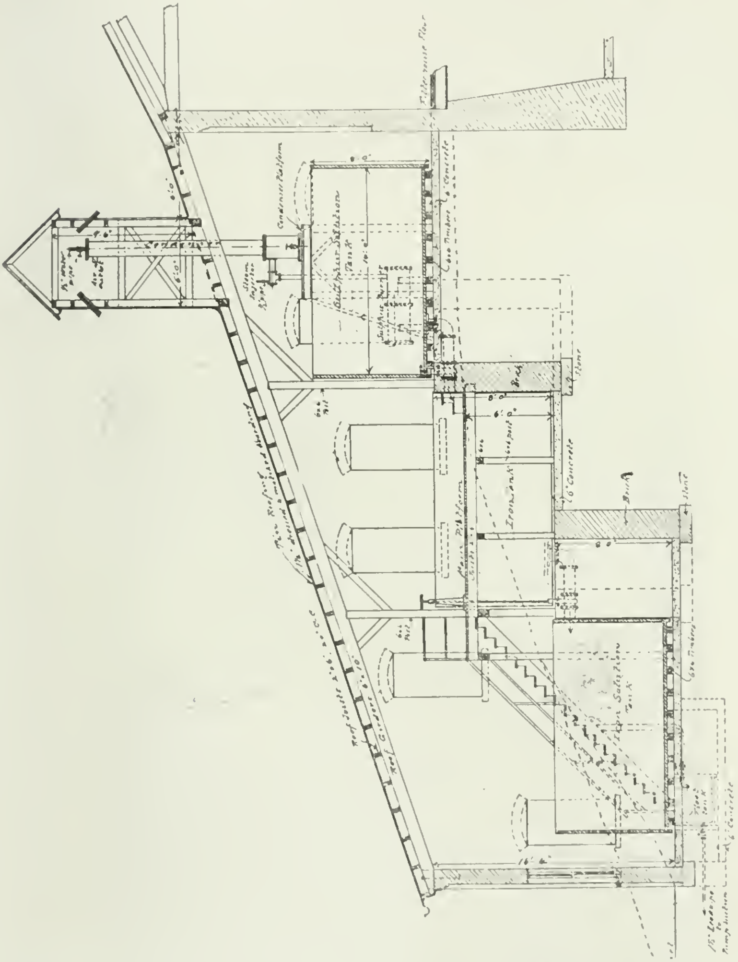
Directly opposite from the rubber connection, on the opposite axle—that is to say, directly opposite from where the solution enters—the satisfied acid solution, or, more correctly speaking, the iron solution, leaves the drum, flowing through a straight piece of cast iron pipe through a wooden trough to the iron storage tank just below, from which it can be pumped by an independent pump to the discharge of the large low-service pumps which feed the filter plant. The crude river water then, containing the iron, is pumped up the hill and at a point about forty feet from where the iron solution enters it, a stream of clear limewater is pumped in by an independent pump to effect the decomposing of the iron solution to the insoluble iron hydrate, in which condition it enters the settling tank, and from the settling tank finally rests upon the filter beds, allowing the purified and clear water to pass through to the clear well. No trace of iron or lime is found upon analysis in the filtered water.

The photograph gives a view of the lime solution tank at Quincy, Ill., showing the slacked lime flowing from the mixing box on top of the lime storage tank. As the slacked lime flows in it is diluted by a stream of water flowing into the bottom of the tank. The arrangement is in duplicate, so that a settled tank of clear lime solution is constantly on hand. The float which shows in the center of tank suspends a floating suction pipe, which on the other end is fastened to a swivel joint. This pipe supplies the independent Worthington pump which feeds the clear lime water to the main, as already described.



Furnace for the Production of Sulphuric Anhydride Gas.

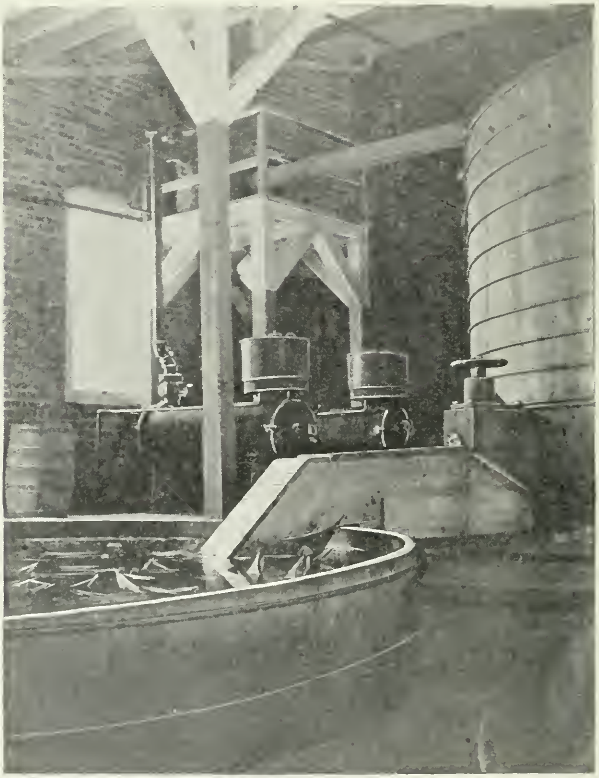
The acid solution is procured in the following manner: Sulphur is burned in a closed furnace, arranged to admit of air, the result being the formation of sulphuric anhydride gas. This gas coming into contact with a steam jet is induced to enter the condenser, described above, at the bottom, and passing upward over surfaces of broken quartz contained within the condenser, meets with a stream of water descending, the result being the absorption of the gas by the water and its accumulation in the bottom of the condenser and storage tank in the form of a weak solution of sulphurous acid, which, as already described, flows to the revolving drum and finally, as a finished product, rests in the iron storage tank. The finished



Section of Filter Plant at Lorain, Ohio.

iron solution in the storage tank is substantially a neutral solution of sulphite of iron.

The iron process is also in use at Lorain, Ohio, the source of supply being Lake Erie contaminated by the Black River. About 3,000,000 gallons of water are purified daily. The method of manufacturing the iron solution differs from the plan in use at Quincy, as described above. At Lorain the scrap iron is stored in large tanks and the acid solution flows to these tanks by gravity, where after alternate contact of six hours the saturated iron solution is drawn off to a tank below, from which an independent pump takes its suction, discharging into the main supplying the settling tanks and filters. With the exception of the iron storage tanks, the process is essentially that in use at Quincy, Ill.



Tank Containing Scrap Iron for Preparation of Sulphite of Iron.

The iron process was sold to the city of Lorain to supplant the alum process, which had been in use successfully there for some five years, and guarantees were given that the iron coagulant would produce bacterial efficiency equal to that which had been produced by the alum process, and at 50 per cent reduction in the cost of operation. So far as bacterial efficiency was concerned, during the test of sixty days, using iron as a coagulant, a gross average of about 98 per cent resulted, and the cost of operation during that period proved to be about $1.40 per million or 60 per cent less than was found to be the case when alum was employed. No particular attention was paid to economy, beyond establishing the guarantee given, while it was desirous to obtain very high bacterial efficiency.

A photographic view which shows the iron scrap stored in tanks at Lorain, Ohio, will give an idea of these iron storage vats. The acid solution passing through them is saturated with iron and rests as a finished product in the iron solution storage tank below, from which it is pumped to the main.

Recent communications from Lorain indicate a saving to the city by the use of the iron process in the last year of about $2,000. One of the advantages of the iron process is that all the factors are within the control of the operator, who literally manufactures his own coagulant, and is not dependent on the market for any portion of his material except the raw material, which does not fluctuate greatly.

In appearance the filtered supply at Lorain was so good that it was possible to read print through 10 feet of water in the clear well. The average bacteria in the raw, unfiltered sample was about 2,000 per cubic centimeter. In the filtered sample, about 40 to the cubic centimeter. During certain days of the test the raw sample ran as high as 30,000, while the filtered sample at no time showed over 200 bacteria to the cubic centimeter.

Recent contracts indicate that the iron process is destined to supercede the more expensive sulphate of alumina, except in cases where peculiar conditions favor the use of the latter.

Between the slow sand system and mechanical filtration it may be said that the cost of installation and operation and the applicability of one or the other, location, etc., are the chief factors used to decide between them.

Much interest has been shown by engineers and others engaged in water-works undertakings in the experiments made from time to time to determine the value of baffling in connection with sedimentation, and the writer has been asked to explain the results claimed to have been accomplished, etc. As a matter of fact it may be stated that sedimentation, if properly carried out in detail and a sufficient period of time allowed, etc., is not dependent on such rearrangement as baffling suggests. On the other hand, where currents are so pronounced as to interfere with the quiescent condition of the settling water, baffling becomes a remedy, and I have come to regard it wholly in the light of a remedy rather than as a primal factor in sedimentation. My own experiences commend height rather than extended shallow surface, in the construction of settling basins of a continuous flow character. It is claimed that by baffling the coagulated water a more intimate and reactionary effect occurs between the introduced coagulant and the carbonates native in the water, and I have seen instances which seemed to corroborate this; but on the other hand it is possible the effects observed were due to other causes not well understood. My observation leads me to believe that chemical reaction is instantaneous, though perhaps the physical manifestation is slower in appearing, yet so far as a proper filtering surface is concerned the full development in size of the particle of coagulum is not essential in practice.

Finally the question of the cost of installation of mechanical filters is of importance to the engineer. Naturally it is difficult to give general figures with accuracy. Such factors as location, turbidity of the water to be handled, condition of the soil and market fluctuations of material operate to cause wide variations of first cost. But as a rough estimate it may be said that $9,000 for each million gallons would cover the installation of the average up-to-date filter plant on the average western supply under the average conditions. This is of course exclusive of buildings and low service pumping machinery, if such be necessary. Such a plant could be guaranteed to deliver 1,000,000 gallons pure, clear water, practically free of turbidity, suspended matter and color, 96 per cent free of bacteria, and where less than 3,000 bacteria exist in the supply, not more than 200 bacteria per cubic centimeter shall be found in the filtered water. In mentioning the above price, I have in mind a plant of about 3,000,000 gallons capacity. Greater capacity than this would imply a reduction in the cost of installation per million gallons.

There is a class of waters which need to be considered by themselves, and are often termed "Algæ" waters. These waters, because of clogging effect they exert upon the filter bed, need careful and separate consideration, and as such do not come within the scope of a paper of this nature.

## DISCUSSION.

*Mr. D. W. Mead*—I have been very greatly interested this evening in Mr. Milligan's description of mechanical filters, and especially in the details of the development of iron as a coagulant.

The subject of filtration is becoming more and more important each year, and mechanical filtration has been and is still being rapidly developed and greatly improved. This paper describes the most modern practice, and is for that reason most acceptable and valuable to water-works engineers.

The whole question of filtration is a comparatively new one, especially in this country, for until a recent period many of our surface water supplies have been comparatively pure and reasonably satisfactory. But the growth in population, which has been very rapid in many localities, has caused an increase in the impurities which find their way into surface waters, and cities depending upon such sources have now in many instances to look for new sources of supply or for some method of purification of their present sources.

In 1829 the first English sand filter was established, and this type of filters have been constructed throughout Great Britain and on the continent, becoming an important adjunct to European water works.

In this country the development of filters for water supplies has been very largely along the line of mechanical filtration. In both the mechanical filter and the slow sand filter as developed in Europe, up to a comparatively recent date, the idea involved has been that of clarifying the water and securing a water which looked all right —which was clear and sparkling. In accomplishing this there has undoubtedly been a considerable purification accomplished. It is only within the last twenty years that sanitarians and engineers have recognized the cause of the development and spread of certain diseases, and that an immense loss of human life and very much sickness are due to impure water. Since these facts have become recognized the true use of filtration has become better understood, and filters are now being delevoped on better sanitary lines.

In the way of study and investigation of this subject, this country has probably done more than any other country. The experiments of the Massachusetts State Board of Health have undoubtedly increased our knowledge very greatly, and the investigations at Louisville, Cincinnati, Pittsburg, Washington, and many of the minor experiments at smaller places, have given us a great deal of information and have prompted a development in both mechanical and slow sand filters, which is considerably in advance of what has been obtained up to a recent date. With the knowledge gained from these experiments and the experience gained on past successes and failures, engineers are now in position to secure better results than have been heretofore possible.

The mechanical details of both systems of filtration are now quite well developed, although great improvements in these features should be expected.

Aside from mechanical details of filtration there are several matters directly bearing on this subject which are of great interest to water-works engineers.

I believe the late Mr. Chesbrough, who was a former President of this Society, is credited with the saying that "the only way to purify water is not to let it get dirty," and while, in a practical way, this may not be strictly true, there is an element of truth in it which makes the question of purification of water a very serious one. For example, the city of Albany, N. Y., is provided with a modern slow sand filter, but at times of flood in the Hudson river the reports from Albany show that the results are at least not all that could be desired. In January, 1900, there was an average of 66,300 bacteria per c. c. in the raw water, and an average of 1,232 bacteria per c. c. in the filtrate. While this is the poorest showing for the year, there were four months where the average bacteria in the filtrate was above 200 per c. c.

While in every case the total reduction was very great, and there was undoubtedly a very great improvement in the quality of the water supplied to Albany compared with the unfiltered river water, yet the question at once arises, "Is such a water a satisfactory water for domestic supply? Is it water that we desire to furnish to a municipality?" That it is an immense improvement, and that in many cases it is all that can be expected, we must admit, but should we be satisfied with these results?

It seems to me there is much more to be done; that there is much more which we need to investigate, and many conditions which must be faced and overcome before filtration—either by slow sand filters or by mechanical filters—can be called a decided success. Even with our present knowledge much better results are possible by longer sedimentation before filtration, by a slower rate of filtration, or by double filtration, but such methods seem to be at present financially impracticable.

One of the most serious difficulties in the way of successful filtration that is encountered in this country is due to the general lack of business judgment and business methods with which our municipalities are conducted. For instance, a municipality will go to great expense to purchase a high duty pumping engine, which will develop a duty of a hundred million foot pounds or more. This engine is run at perhaps 25 per cent of its capacity, with a resulting duty of less than half the guarantee. Our municipalities expect to purchase economy by a large outlay of first cost regardless of future methods of operation. The same thing is done in connection with pavements. Our cities construct an expensive pavement and then let it take care of itself, when proper care is necessary to prolong its life and make it satisfactory and economical. The same method also prevails in regard to filtration. The municipalities act on the general proposition that if a filter is once purchased ,the question of the purity of the water supply is settled for all time to come, and that care in operation is unnecessary. The result, as would naturally be expected, is very unsatisfactory. There is, I think, at the present time, but one city in the United States that employs a permanent chemist and bacteriologist. Most of the larger filter plants employ a chemist and bacteriologist occasionally to keep track of the general run of the work. The balance of the time the filters are operated very largely by guess or by the eye; that is, the filtrate is judged by its looks. Without doubt the looks of the water is a very fair criterion, for a decided improvement in the appearance of most surface waters means a decided improvement in their sanitary condition as well, but appearance only is not a safe or satisfactory criterion for the operation of filters.

I had occasion during the last year to look over a number of filter plants in the east and west, and I found that in very few places are the cities securing a uniformly satisfactory filtrate. The filtrate at certain seasons, on account of floods or on account of carelessness, is left in a very bad condition, while at other times it is fairly satisfactory.

In making these statements I am not arguing against the use of filters, but I am citicising the operation of filters as we find them, and I am endeavoring to point out that it is this question of operation that is the most serious question that we have to answer satisfactorily when installing filters. I remember within a year of looking over a filter system in a town of about 15,000 inhabitants, where the system had been in use for some years, but where it was used apparently more to satisfy popular demands than for sanitary reasons, and inquiring of the superintendent as to the amount of coagulant he ordinarily used, he told me that they ordinarily used about three grains of sulphate of alumina to the thousand gallons. The result obtained by the filters showed clearly that that was about the amount used, whereas the amount probably should have been about a thousand times as great.

In another case where I was inspecting a filter system, the superintendent in charge was showing me the arrangement for regulating the coagulant, and in going to one filter not in operation he opened the valve to allow the amount of coagulant required to pass through and found that in some way the coagulant tank had become empty and the filter had been operating for some time without the use of the coagulant, and, of course, during that time the results were not such as the filter should have given.

In still another case, where a slow sand filter was installed, and where the filters were in a condition to give, at least, a fair filtrate if they had been carefully and thoughtfully operated, it was found that on account of the formation of ice considerable expense would be entailed by its removal and by the proper cleaning of the filters. Without any notice to the public the filters were allowed to silt up, and when no more water would pass the filters, the raw river water was turned through a by-pass and allowed to pass without filtration into the clear water basin. Much sickness and a number of deaths resulted in consequence.

The above examples, and many similar ones which might be quoted, emphasize the fact which should be, but apparently is not, clear to all, that filtration demands for its success the greatest care and continued expert management and supervision. The need of such supervision is perhaps best illustrated by the following table taken from the report of Mr. Fuller on the investigation of filtration at Cincinnati. The table shows the quantity of coagulant needed for each day in the year at Cincinnati: (See page 342, Report on Water Purification.)

Table showing the Estimated Quantity of Applied Chemical (Sulphate of Alumina) in Grains per Gallon of Filtered Water required for each day of 1898, when the Applied Water received Preliminary Plain Subsidence for three Days.

| Day | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.6 | 1.5 | 1.5 | 1.3 | 2.1 | 1.6 | 1.6 | 2.2 | 1.3 | 0.8 | 2.0 | 1.2 |
| 2 | 1.8 | 1.8 | 0.8 | 1.3 | 1.7 | 1.6 | 1.3 | 2.0 | 1.1 | 0.8 | 1.6 | 1.3 |
| 3 | 2.4 | 2.1 | 1.2 | 1.5 | 1.3 | 1.7 | 1.2 | 2.0 | 1.1 | 0.7 | 1.5 | 0.8 |
| 4 | 2.2 | 1.6 | 1.3 | 1.5 | 1.3 | 1.3 | 1.1 | 2.0 | 1.1 | 0.8 | 1.3 | 1.2 |
| 5 | 1.9 | 1.4 | 1.3 | 1.5 | 1.4 | 1.4 | 1.2 | 2.0 | 1.0 | 0.8 | 1.3 | 2.4 |
| 6 | 1.6 | 1.3 | 1.2 | 2.0 | 1.5 | 1.5 | 1.4 | 2.2 | 0.9 | 0.8 | 1.3 | 2.3 |
| 7 | 2.8 | 1.3 | 1.1 | 1.9 | 2.2 | 1.0 | 1.5 | 3.1 | 0.8 | 0.8 | 1.3 | 1.9 |
| 8 | 3.0 | 1.2 | 0.9 | 1.5 | 2.0 | 1.0 | 1.1 | 3.3 | 0.8 | 0.7 | 1.3 | 1.7 |
| 9 | 3.7 | 1.2 | 1.2 | 2.2 | 2.0 | 0.9 | 1.2 | 3.8 | 0.8 | 0.7 | 1.9 | 1.8 |
| 10 | 5.4 | 1.5 | 1.7 | 1.5 | 2.0 | 0.9 | 1.1 | 3.0 | 0.7 | 0.9 | 2.4 | 1.8 |
| 11 | 3.6 | 1.8 | 2.0 | 1.6 | 1.7 | 0.8 | 1.0 | 3.3 | 1.2 | 0.9 | 2.3 | 1.6 |
| 12 | 3.4 | 2.2 | 2.2 | 1.5 | 1.8 | 1.8 | 1.0 | 3.9 | 0.8 | 0.9 | 1.9 | 1.4 |
| 13 | 2.9 | 2.1 | 2.0 | 1.6 | 1.7 | 1.0 | 1.0 | 2.7 | 0.9 | 0.9 | 2.4 | 1.5 |
| 14 | 2.6 | 1.6 | 1.7 | 1.3 | 1.3 | 1.0 | 0.9 | 2.2 | 0.7 | 0.9 | 2.6 | 1.1 |
| 15 | 2.4 | 2.3 | 1.2 | 1.2 | 1.5 | 1.1 | 1.1 | 1.6 | 0.8 | 0.7 | 2.4 | 0.8 |
| 16 | 2.3 | 1.8 | 1.5 | 1.3 | 1.5 | 0.7 | 1.1 | 2.1 | 1.4 | 0.7 | 2.2 | 0.7 |
| 17 | 2.2 | 1.8 | 2.2 | 1.0 | 1.4 | 0.7 | 1.1 | 2.5 | 0.8 | 1.8 | 1.9 | 0.7 |
| 18 | 2.0 | 1.7 | 2.8 | 1.2 | 1.2 | 0.8 | 1.1 | 2.8 | 0.7 | 0.8 | 1.8 | 0.7 |
| 19 | 2.0 | 1.6 | 1.9 | 1.5 | 1.5 | 0.7 | 1.8 | 2.4 | 1.2 | 0.8 | 1.6 | 0.8 |
| 20 | 2.0 | 2.2 | 2.4 | 1.8 | 2.2 | 1.0 | 2.1 | 2.5 | 1.5 | 0.8 | 1.7 | 3.6 |
| 21 | 2.1 | 1.9 | 3.0 | 1.0 | 2.2 | 1.2 | 2.0 | 2.2 | 1.8 | 0.8 | 1.6 | 1.9 |
| 22 | 1.9 | 1.5 | 2.4 | 1.0 | 2.0 | 1.3 | 1.9 | 1.9 | 1.8 | 0.8 | 1.5 | 2.2 |
| 23 | 2.2 | 2.0 | 2.1 | 1.0 | 2.0 | 1.5 | 1.6 | 1.8 | 1.3 | 0.9 | 1.5 | 2.1 |
| 24 | 2.5 | 1.7 | 2.5 | 1.4 | 1.7 | 1.6 | 1.3 | 2.5 | 1.3 | 1.4 | 1.5 | 2.0 |
| 25 | 2.5 | 2.0 | 2.3 | 1.8 | 1.3 | 1.5 | 1.5 | 2.8 | 1.2 | 2.4 | 1.1 | 2.1 |
| 26 | 2.6 | 1.5 | 2.0 | 1.0 | 2.0 | 1.5 | 2.2 | 9.6 | 1.1 | 2.6 | 1.2 | 2.1 |
| 27 | 2.6 | 1.3 | 2.0 | 1.0 | 1.6 | 1.5 | 2.7 | 2.3 | 1.3 | 2.2 | 1.3 | 2.1 |
| 28 | 1.9 | 1.4 | 2.0 | 1.7 | 1.5 | 1.5 | 3.2 | 2.1 | 1.1 | 2.1 | 1.3 | 1.8 |
| 29 | 1.9 | ... | 2.0 | 1.9 | 1.6 | 1.7 | 1.9 | 1.8 | 1.0 | 1.9 | 1.3 | 1.5 |
| 30 | 1.7 | ... | 1.8 | 2.3 | 1.5 | 1.8 | 2.1 | 1.6 | 0.9 | 1.7 | 1.2 | 1.3 |
| 31 | 0.9 | ... | 1.1 | ... | 1.6 | ... | 2.3 | 1.1 | ... | 1.9 | ... | 1.9 |

With such variations as these it is impossible to attain satisfactory results without constant skilled supervision.

It is always, in my opinion, most desirable to avoid the necessity of fallible agencies wherever possible, and to adopt the infallible where such can be secured by careful study and at a reasonable expense.

In the human mind the best results are obtained by concentration, rather than by continuous effort. Hence we may plan to better advantage for the utilization of sources of water supply, which need expert knowledge and correct construction at the outset for their maximum and continuous efficiency, rather than those which need continuous exertion and unrelaxed vigilance to accomplish these results.

To this extent I am a believer in securing, wherever it is reasonably possible, even at considerable extra expense, a pure water supply, rather than attempt to purify a polluted water. There are, however, many places in this country where a pure water supply is out of the question, and in such cases the engineer must of necessity face the very serious problem of filtration, and the most serious part of this question comes after the design of the filter system is perfected, in securing the results which he has the right to anticipate from such a design. Management and maintenance are, I believe, the most serious features in the way of successful filtration today, especially in the smaller municipalities.

*Mr. Benezette Williams*—I would like to corroborate what Mr. Mead has just said. I think that beyond all doubt the first thing an engineer, in looking for a water supply, should consider, is, "Can the supply be obtained that will not need purifying, and if so, can it be obtained at a cost within the means of the municipality or water company seeking the supply?" If this can be done, it should be done. This judgment is based upon experience in the operation of filter plants. I doubt if there are half a dozen filter plants in the United States today that are run conscientiously on any thoroughly scientific basis. With the most of them, on becoming acquainted with their operation, it will be found that but little is known of their efficiency, or as to the amount of coagulant used, except as to how much is bought in a year, if it is a mechanical filtration plant. Generally it will be found that during the periods of low water, or when the water is least turbid, no coagulant at all is used.

I have in mind a plant, probably the one that Mr. Mead has referred to, where the water passed through the filter continuously, but I doubt if they used a barrel of coagulant a year. The filters were used more to satisfy public sentiment than anything else. So it is with almost all of the plants that I have ever seen; in fact, I can say *all* that I have seen. There are doubtless some I have not seen that are different. Many of them are operated simply to keep water users quiet, and whenever the water is apparently clear enough, so that they can pass it without coagulation, they do it. Even if systematic care is aimed at, owing to the difficulties of the problem in many cases good results are not obtained. To obtain good results so much coagulant is necessary that the cost is a continual bribe to low efficiency.

There are great varieties of water in this country. With some of them, particularly the water from the Mississippi, Missouri and Ohio rivers, it is a serious problem to get rid of the sediment, and carry on a system of filtration that will be efficient both as to hygienic qualities and clarification.

Where slow sand filters are in use, in a few places, such as Lawrence and Albany, a more watchful care is had of the results and of the processes. For these reasons I believe that water-works engineers should always try to find a supply that does not need filtration. If there is no such supply to be had, then of course filtration must be adopted. Filtration is certainly a great improvement to polluted waters, and for this reason should be developed and carried forward to its most perfect stage.

*Mr. Finley*—I was just wondering, in connection with the case where the water was allowed to go through the filters without the proper coagulant, if the suggestive effect might not have been beneficial to the people.

*Mr. James A. Seddon*—It has been some years since I have had occasion to deal with this problem, although ten years ago I had to study the question for the St. Louis water supply, and went into it at that time very thoroughly. I reached then certain conclusions, and although they may not be fully up to date, in following the literature of the subject, I have not had occasion to change my mind in the matter.

After a city has secured a suitable water supply, the question then comes in to improve its quality; and I think it is well to face this question, not from the fixed conviction that mechanical filters, slow sand filtration or any other treatment is the right thing in all cases. I believe the problem is best approached by first considering the character of the water. Where the water is taken from the river, the sediment that it carries in its flood period is the most immediate and direct injury to its quality, and in many cases, with that removed, it may be a considerable period of time before a further improvement in quality is necessary. This sediment borne by the flood waters varies greatly in different rivers. As I carry it roughly in mind from my studies of this subject, the Mississippi carries, below the junction of the St. Croix near St. Paul, a flood water sediment that will average about 3 by weight in parts per thousand. This is reduced to about half this amount below Lake Pepin, and rises again to from 4 to 6 parts per thousand when it reaches the mouth of the Missouri. Sediment in the Illinois river has not been studied, but I should be greatly surprised if the Chicago Drainage Canal, including its flood waters, exceeded an average of 1 in parts per thousand. The Ohio river, where its flood water sediment has been determined, has rather less than 2 in parts per thousand, while in strong contrast to all of these the Missouri river carries a flood water sediment of from 7 to 9 in parts per thousand.

When we see the different character of the waters in these different rivers, it is plain that a filter system that operated satisfactorily in one case might be altogether unfit for another. At the time that I was studying the St. Louis water supply, which consisted mostly of Missouri river water, the mechanical filter men were as persistent as they are today. Indeed, in one case I remember that one of them proposed to run an amount of water through a pressure filter that would fill it up with mud solid, sand spaces and all, about twice in twenty-four hours. The mechanical filters have certainly done good work at some points on the Ohio and Mississippi, and I have a high respect for the men that have been developing this matter and great sympathy with their work, and they have made much progress since the time when I was studying the question; but I do not feel that they have yet solved the problem of the Missouri river water, and, indeed, when I was studying it ten years ago, I had to keep them off my problem with a club.

Outlining the subject as I still look at it, the first step is to take out of the water the flood sediment, and the cheapest way to do this, I think, will be by sedimentation. It is a very simple process, calling for no expert supervision, and costs for some thirty-six hours of settlement about $1.00 per million gallons. This removes about 85 per cent of the flood sediment, and improves the water supply very markedly.

At the next step in improving the water supply we meet the question of whether we shall throw away the work we have done and do something different, or whether we shall develop the improvement of the water supply progressively. I believe that, before the sedimentation system that has been wisely put in is abandoned, it should be very thoroughly tested as to what can be done with sedimentation and coagulation — something on the line that Kirsted has been following at Kansas City. Thirty-six hours of settlement with a small amount of coagulant may be found to give a sufficiently marked improvement to meet the requirements for years, and it introduces the expert treatment of the water gradually, at first only in the flood period, and at small expense in the operation. With this carried to its economical limit we are brought finally, for both security to health and for reaching the highest improvement possible of the water supply, to the filter system. I believe that the filter system should follow these other treatments and deal with the effluent from them as if it were the original water supply to be handled. The sediment in that case is a small fraction of 1 by weight in parts per thousand, and is of a character that can only be economically removed by filtration, while for bacterial purification, filtration is probably necessary. Whether in this final step the mechanical filter system will supplant the slow sand filter systems of other countries is a matter that I do not feel qualified to give an opinion. It is the American system, and as such is entitled at least to an unprejudiced consideration by Americans (which it has not already received), and from what I know of the men who are developing it, I would not be at all surprised to see it come out ahead and beat the world as a filter for the future, but that is for time to determine.

I was very much interested in the development of the iron process in the treatment of the Quincy water supply, and would like to ask the author if any extended studies have been made on the lime coagulant. At the time I was looking into the matter it seemed to me that something in the nature of Clark's process of softening water was a very hopeful field to work on. The addition of lime to waters carrying bicarbonate of lime in solution forms the insoluble precipitate of carbonate of lime, which is a very good coagulant, but the difficulty is that our river waters are not hard enough to give a sufficiently large coagulation to aid sedimentation. I thought at the time that the waters might be made artificially harder, so that they would take a sufficient amount of lime to take the place of alum in the clearing. I have not seen any accounts of experiments on that line, and do not know whether anything has been done on it or not, but it seemed to me that it was certainly worth looking into.

*Mr. Milligan*—In answering Mr. Seddon, let me say that there have been and still are many chemists working along that line. In fact, the iron process, to some extent, covers that very field, from the fact that an excess of lime water is added to equalize the carbonic acid before it is allowed to come in contact with the iron solution. The Clark process referred to is best explained by considering that the carbonate of lime is in itself insoluble, but is held in solution by the carbonic acid gas present. To equalize the carbonic acid in the water by adding lime water means the precipitation not only of the carbonate of lime that was once in solution, but the added carbonate of lime you injected. It has been claimed for the iron process that in that respect it is a saving factor.

I would like to say further that it is not possible for engineers to know all the research that has been made along the line of mechanical filtration, and it forces me to say that I myself, young as I am, have experimented for years with the Mississippi river, the Missouri, the Ohio, the Allegheny, Raritan, Passaic, etc. What the mechanical filter rests upon today is general conditions. For any advocate of mechanical filters to claim that it is a panacea is just as ridiculous as to say that the gravity supply of a city is the only available method of supplying water to consumers. No engineer today would advocate the use of pumps for water if it was possible to secure a gravity supply, and certainly no sound man would advocate the use of filters if a pure supply of water could be had. There is a place for mechanical filtration. What I desired to present before you were such facts as I myself knew and such explanation as I was capable of giving you as to just what mechanical filtration consisted of. Of course I know that some of you must be well informed in that line, but I do know that many engineers have not had time to consider mechanical filtration at all. It has been brought to their attention through necessity, and I had thought that information along this line, which unfortunately is very often held as a business scheme, would be of some benefit to a society of engineers. Mr. Mead and I do not differ one iota on the artesian well system. I also know where the three grains of alum to the thousand gallons are employed. That was surely an oversight. I can appreciate the harrowing experiences of Mr. Williams in the last few months, and know he has had the sympathy of every one.

But what I want to say is this: that there is a place for all things in the universe. As cities grow larger the sources of supply become more polluted. The ground waters are becoming more and more exhausted with the increase in population. It is one thing to draw 200,000 or 1,000,000 gallons of water from a well and it is another thing to attempt to draw a hundred million. There is one thing I have often said before councils; that is, that no inhabitant, old as he might be, has ever seen the Mississippi, the Missouri or the Ohio river run dry. Artesian wells may come and may go, but there is something stable about a water supply that no man has ever seen run dry, and I think it would be well for all engineers to take into consideration every practical method of rendering pure or partially pure the supply of water to a city.

*Mr. Benezette Williams* It is not meant to convey the idea that there is no place for mechanical filters, and I am glad to find that the author of this valuable paper is at one with my ideas. However, if there is a place where water can be obtained that does not need filtration, that is the source from which to get it. If there is no such source, then the thing to do is to apply filtration in the best manner, and to operate the filters in the best manner. But first of all, be sure that no good and adequate supply is to be had that does not require purification. There is a disposition to advocate filters, and such plants have, I believe, been put in, and are being put in, in some cases very much against the interests of the communities that they are to serve; that is, where pure water could have been obtained at probably no greater expense than thorough filtration involves. My remarks were directed against such a course, and not against filtration in itself. If a city can obtain no other supply than a polluted supply, that is the place for filters—there is no question about that.

In regard to the sediment carried by some of the waters Mr. Seddon mentions, it may be said that at Cincinnati the average annual sedimentation there is about 230 per million parts. At Louisville it runs considerably greater, being about 350 parts, and at the St. Louis water works intake it will average at least 1,200 parts during the year; sometimes it runs over 5,000. The river itself carries an average of 1,500 parts, but it drops a good deal of its sediment before the water enters the intakes.

*Mr. Finley*—Last summer I was engaged in some work on the Missouri river, and our only source of drinking-water was from the river. We filled some wooden pails, put ice in them, and after the water got reasonably clear we drank it. Since Mr. Seddon has told us about the amount of sediment in that water, I regret that I drank it.

One point occurs to me, and that is, it may be possible to get a source of supply that does not need filtration, and yet it may not be a reliable source of supply. Would it not be better, in such a case, to have a source that is reliable, even though it needed filtration?

*Mr. C. B. Burdick*—There is one subject connected closely with filtration which Mr. Milligan has touched on, and that is the subject of sedimentation. In looking through various books and reports on water supply, I notice considerable difference of opinion as to the proper shape and form of basins which are used in the purification, or partial purification, of water by settling. One author, I remember, stated that the best form was a long, shallow basin; another held that depth is not an important consideration. There are many other important points in the design of these basins, upon which the opinions of engineers differ considerably, and upon which there is to be found very little reliable data. In reading the report of the filtration experiments at Louisville (or Cincinnati, I do not remember which) I noticed that they used vertical tubs, about ten feet in diameter, I should say, and twelve feet perhaps in height. Some experiments were made in these vertical tubs to determine whether the water, being admitted at the bottom and taken off at the top, passed through the tubs at a uniform rate throughout the cross-section of the tub, or whether it short-circuited or tended to seek a direct path from the inlet to the outlet. It was determined by these experiments that baffles inserted in the tubs produced a more uniform flow. I would like to ask the author of this paper whether or not baffles were used in the Cairo settling basins? That was a continuous flow plant, I understand.

*Mr. Milligan* —They were not; but what you say about baffles is substantially correct. Mr. E. B. Weston, of Providence, is a very strong advocate of the use of baffles to increase the time the water takes between the inlet and outlet. My own experience is that practical benefit lies rather in increasing the height than the length. At Cairo the tanks were long rather than broad. To baffle them would be rather difficult. I managed by valve effects to control the water going to the settling tanks so that they ran an even quantity to each settling tank, and they were controlled in that way.

Unfortunately all that Mr. Williams and all that Mr. Mead has said is true concerning the bad operation. Of course, that is something over which the builders of filter plants have no control whatever. It is often the case that experts, who get the highest possible efficiency out of filter plants that are allowed to deteriorate in their absence, can go back and bring them right up to their efficiency again.

At Lorain, Ohio (after six years, when a plant might have been considered not to be in its very best condition, and had been very badly handled), I was able to get 98 per cent bacterial efficiency from a plant that really needed overhauling. It was a question of whether expert ability could get something out of a plant that an ordinary operator, getting $50.00 or $75.00 a month, could not get.

I look forward with great eagerness to the day when the plant will get into good hands as well as leave good hands. Mr. Weston would tell you that baffling is a very essential feature. Today the tendency in sedimentation tanks is to construct them of masonry, rectangular in shape and with baffle interiors.

*Prof. J. B. Johnson* I have been very much interested in this paper of Mr. Milligan's. I think it is a valuable one, and that we will all agree that it was presented in a thoroughly scientific spirit, and I believe the statements can be relied upon. There are some features of it, concerning the use of iron in these filters, that were entirely new to me, and I suspect they will be new to many of the readers of the JOURNAL. That fact alone is well worth bringing to our attention.

Concerning the point of the use of baffle plates, I designed a plant for Jefferson City, Mo., with a view of getting the greatest possible area out of a single settling basin. I used these baffle plates, so called, to rather an extravagant extent. I divided the basins by vertical walls into a series of chambers, these walls being double and passing the water from the top of one chamber down through the hollow partition into the bottom of the next. Each chamber was subdivided by horizontal floors, the total depth being some 18 feet, and having four sections vertically, the flow being over these floors, alternating from side to side so as to get the greatest amount of settling area. Unfortunately, just as the works were about to be built, I was taken sick and was confined to my house for six months, so the plant, I am sorry to say, was not built as it should have been. They built these partitions out of common lumber to save expense, and were not very particular about how they attached them to the masonry walls. The result was, these partitions were comparatively porous, and when I got around to it I found that, although they really did get a clear effluent, a considerable portion of the water was passing through the partitions. I found also that the basins, which were intended to be covered, were not covered. During warm weather the water on the top would be heated and the water coming in from the river would be cooler, and this cold water tended to move through the partitions at the bottom of the basin, and leave the warm water floating on top. There was then little vertical interchange in the water. So the whole thing was very imperfectly operated, but still it gave an almost perfectly clear effluent under constant flow, the water being taken from the Missouri river. It is still working, so that if it had been more perfectly executed I am satisfied it would have shown remarkable results. I have often been asked to describe these works, but the plant was so imperfectly executed that I have not felt that I could do so.

# ABSTRACT OF MINUTES OF THE SOCIETY.

## *REGULAR MEETING—March 5, 1902.*

A regular meeting (No. 466) of the Western Society of Engineers was held March 5th, 1902. The meeting was called to order about 8:20 P. M. with President Finley in the chair and forty members and guests present.

The minutes of the preceding meeting were read and approved.

The Secretary presented the following list of new members elected into the Society at a meeting of the Board of Direction on March 4th:

C. D. Bedford, Chicago, Associate.
L. D. Vorce, Chicago, Active.
Sutton Van Pelt, Greenwood, Ala., Junior.
Wm. Pierce Hoppin, 6201 Woodlawn avenue, Junior.
Maro Johnson 5412 Washington avenue, Junior.
Robt. I. Randolph Riverside, Ill., Junior.
F. A. Flather, Chicago, Active.
M. W Tenny, Holly, Mich., tranfer from Junior to Active.
Wm Meier, 300 N. Paulina street, Chicago, Junior.
Wm. A Theodorson, 19 Milton avenue, Chicago, Junior
Edgar B. Thompson, Oak Park, Ill., Active.
J. C. Quade, Kewanee, Ill., transfer from Junior to Active.

Also the following list of new applicants for membership was read:

W. W. Gaffin, Sioux City, Iowa, Active.
Chas. J. Poetsch, Milwaukee, Wis , Active.
Burton W. Perrigo, Milwaukee, Wis., Active.
Robt. Kuntsman, 84 Adams street, Chicago, Active.
W. T. Curtis, Wilmette, Ill., Active.
James H. Dunbar, La Salle, Ill., Active.
Euclid P. Worden, Milwaukee, Wis., Active.
Wm. T Reeves, Chicago, Active.
Harrison S. Bowen, The Rookery, Chicago, Active
Gwavas F. Beckerleg, Chicago, transfer from Junior to Active.
Frank E. Hermanns, Chicago, Junior.
Myron W. Priseler, Chicago, Junior.
Jas. C. Hain, Chicago, Active.
Chas. Dunham, Chicago, Associate.

After the transaction of this routine business, the President introduced Mr. W. M. Torrance, who gave a résumé of his paper (which had been sent out in advance) on Transition Spirals in Railroad Work.

Following this, the Secretary read discussion by letter from

R. P. Morgan, of Dwight, Ill.
A. M Haynes, of Denver.
Willard Beahan, of Winona, Minn.
Prof. A. N. Talbot, of Champaign, Ill.
A. A. Schenck, of Boone, Iowa.

The reading of these letters was followed by discussion by Messrs. Geo. H. Bremner, John A. Fulton and F. K. Vial.

At the conclusion of the meeting Mr. Isham Randolph presented to the Society a paper to be placed on file which Mr. R. P. Morgan had sent to Mr. Randolph, on the subject of the development and progress of rapid transit in the state of New York, in which line Mr. Morgan had spent a number of the earlier years of his life.

The meeting adjourned about 10:20 P. M.

## *SPECIAL MEETING—March 10, 1902.*

A special meeting of the Society (No. 467) was held March 19th The meeting was called to order at about 8:20, with President Finley presiding, and fifty members and guests present.

As this was a special meeting no business was brought before the Society.

Mr. F. R. Still, of the American Blower Company, Detroit, was introduced, who read a paper on "Mechanical Draft," which was illustrated with lantern slides. Following the reading of his paper there was a discussion of the subject by Messrs. Damon, Arnold, C W. Rogers, W. E Williams and Prof. Kerr.

The meeting adjourned about 10 o'clock.

# WESTERN SOCIETY OF ENGINEERS

Secretary's Office, Library, Reading Room and Meeting Room
1734-41 Monadnock Block, Chicago

## LIST OF OFFICERS FOR 1902

| | |
|---|---|
| President | W. H. Finley |
| First Vice-President | Ralph Modjeski |
| Second Vice-President | Prof. L. P. Breckenridge |
| Treasurer | Andrews Allen |

## TRUSTEES

| | |
|---|---|
| B. J. Arnold | Term expires January, 1903 |
| C. W. Hotchkiss | Term expires January, 1904 |
| J. W. Alvord | Term expires January, 1905 |

**The above named officers of the Society constitute its Board of Direction**

Secretary and Librarian
J. H. WARDER

## COMMITTEES

*On Finance*—Ralph Modjeski, Andrews Allen, Daniel Royse.
*On Publication*—T. W. Snow, F. H. Bainbridge, Prof. L. P. Breckenridge.
*On Membership*—C. W. Hotchkiss, C. L. Strobel, Wm. M. Hughes.
*On Library*—J. W. Alvord, B. J. Arnold, Benj. Wolhaupter.
*On Entertainment*—W. J. Karner, C. W. Melcher, J. H. Spengler.

## MEETINGS.

Annual Meeting—The first Tuesday evening after the 1st day of January.

Regular Meetings—1st Wednesday evening of each month except January, July and August.

Special Meetings—3d Wednesday evening of each month except July and August.

Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

## NOTICE

From the dues of each member $2.00 is set aside as a subscription to the Journal.

Journal of the
Western Society of Engineers.

VOL. VII. JUNE, 1902. NO. 3.

## CXLV.

# WET, DRY, OR MEDIUM CONCRETE.

H. W. Parkhurst, M. W. S. E.

*Read April 2, 1902.*

Shall we make our concrete dry or wet; or is there, somewhere "a golden mean," by striving for which we may attain perfection?

The writer has for many years been engaged in the construction of concrete masonry, and was specially interested in paper No. CIII, which appeared in No. 6, Vol. V, of the Journal of this Society (December, 1900), which paper described "An Experiment with Wet and Dry Concrete."

Believing, however, that the inferences drawn from that experiment were not fully warranted, the writer, assisted by Mr. H. H. Hadsall (Junior Member of the Society), repeated—with some modifications—the experiment narrated in the paper referred to, and feels justified in presenting the results to the Society in a tabular comparison of the two sets of experiments, together with some conclusions drawn therefrom.

The modifications referred to were as follows:

1st. Instead of making exactly a cubic yard of concrete, a barrel of cement was taken as the unit, and the four sacks making a barrel were dumped loosely into a box, and that box (containing 4.42 cu. ft. when level full) was used as the measure of volume for all materials, which were all measured "loose." As a check, each boxful was weighed, and the weights of each charge, as summed up, are given in the table. The water was also both measured and weighed.

It seemed proper to make this modification, inasmuch as this would be the natural order of concrete making; for, in practice, we do not gauge our ingredients to produce a fixed amount, but measure them separately, as may be convenient, and let the result be what it may. To work the other way, introduces possibilities of error in the determination of the volume and amount of the ingredients used. By comparing the actual weights of the cement, sand, gravel and crushed stone used in the three concrete blocks made, it will be observed that the weight varied as follows:

| | | | | |
|---|---|---|---|---|
| Cement | 3 % | above | lesser | weight. |
| Sand | 1.5 % | " | " | " |
| Gravel | 2 % to 4.2 % | " | " | " |
| Crushed stone | 2.5 % | " | " | " |

The volume was, however, made the unit of measure, rather than the weight, since this is the general custom.

It will be observed, further, that the gross weight of all materials used (except water) in the *dry* block was 2.3 per cent greater than in the *wet* one, while the *wet* and *medium* blocks had almost exactly the same gross weight of solid contents. The *wet* block, as compared with the *medium*, had 13 lbs. more sand and 3½ lbs. more of crushed stone, but 19½ lbs. less gravel.

2d In the later experiment, while mixing gravel with the crushed stone to make up the required volume of the grosser material, the sand was separated from it, and exact measures of each were used, making a more definitely composed mixture.

3d. *Three*, instead of *two*, blocks were made, in the belief that a medium mixture would be as good or better than the *wet* one. The volume of water in the several mixtures was as follows:

| Former experiment | | water— | New experiment | |
|---|---|---|---|---|
| Former experiment—dry | 5.5% | water— | New experiment—dry | 5.1% |
| " wet | 10.4% | " | " wet | 9.5% |
| | | | Medium | 7.5% |

In the later experiment it was the endeavor to get enough water in the dry block to make a mealy concrete, but not to flush it. No amount of ramming the thin layers would bring water to the surface. In the wet block, men could not stand on the concrete to ram it; the mass quaked easily, and the mortar stuck to the tamping iron. In the *medium* block there was enough water so that the top of each layer was flushed by the tamping, but there was no quaking, the mass being always hard. The top surface had enough free water on it to spatter when the tamping was finished.

4th Instead of breaking the blocks at the age of 30 days, it was thought advisable to leave them exposed to the sun, rain, snow, etc., for several months, and to weigh them from time to time and see whether the wet block lost water, and the dry one gained any, also how the medium block showed in this respect.

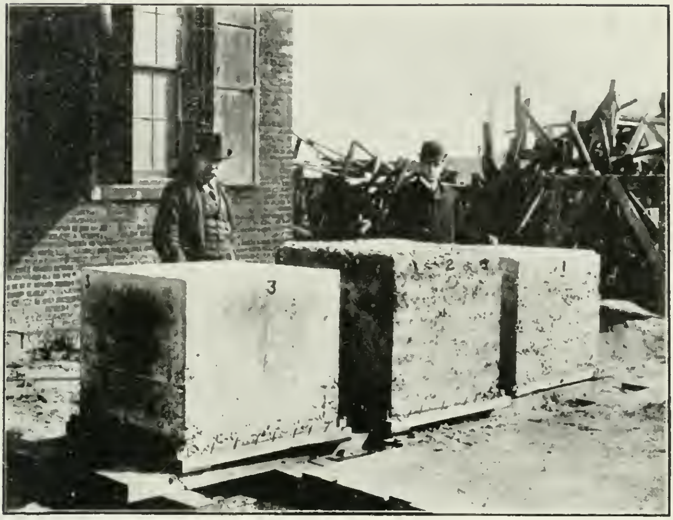
5th. When ten months old, the blocks were drilled and broken by plug and feather, in same style as in the earlier experiment.

Having mentioned the differences from the former experiment, it is proper to describe the later one more in detail. The cement used was the "Dragon" Portland cement, made by The Lawrence Cement Company, of Siegfried, Pennsylvania. The sand was "torpedo," from Fox River, near Coleman, Illinois, and the gravel was from same place, both got by a washing plant, and therefore very clean and good. Crushed stone was the ordinary "medium," from Dolese & Shepard's Hawthorne quarry.

The following table gives data as to these materials:

| | Sand. | Gravel. | Stone. | Cement. |
|---|---|---|---|---|
| Per cent of voids | 25 | 32 | 44 | |
| Average weight per cu. ft | 102 lb. | 98 lb. | 84 lb. | 88 lb. |
| Specific gravity | 1.63 | 1.57 | 1.35 | 1.41 |

The concrete was mixed by hand on a plank platform adjacent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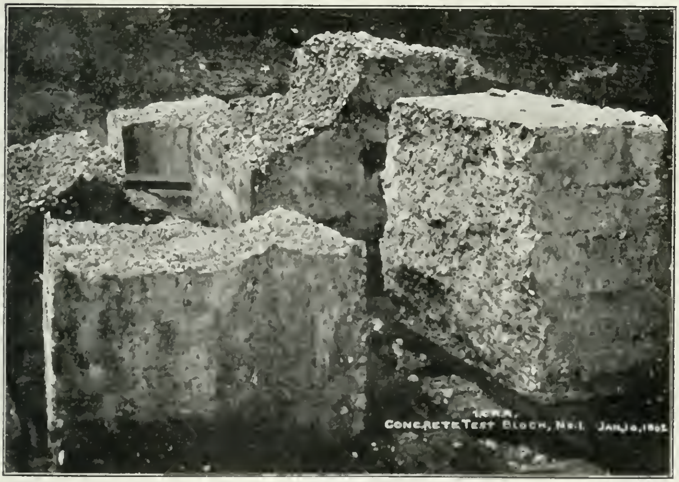
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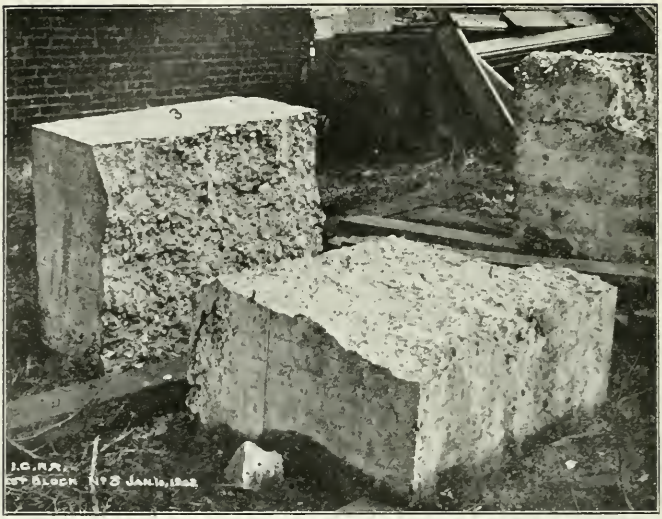
CONCRETE TEST BLOCK, No. 1. JAN 10, 1902



to the molds (shown in illustrations). The materials for each batch were measured as above described. Sand and cement were made into a mortar, and the crushed stone and gravel spread thereon, all turned over several times by shovels, and then shoveled into the boxes, made ready adjacent to platform, and the whole was tamped in layers 6 inches thick, as shoveled in. Note that the medium mixture was put into box in 21 minutes, the dry in 25, and the wet in 23 minutes. The dry required and received most tamping, but the wet took nearly as long to put into mold, on account of the small amount that could be handled on each shovel. The illustrations show the front and rear views of each block. The surface of No. 3 (the wet mixture) was the best, No. 1 (the medium) next, and No. 2 (the dry) the poorest. There was not enough water in the dry block to permit a finish either to the side or top, and the surface could be easily abraded, and small pieces picked off by the fingers. The gravel and stone came away from the mass quite easily, and the block could not be handled to weigh it without crumbling edges and top surface.

After the blocks were finished, the surplus water on blocks No. 1 and No. 3 froze; but this freezing was of short duration, as the weather grew warmer, and the water had disappeared when the blocks were weighed. The second measurement for volume given in the table corresponds to the weight.

The blocks stood for about four months exposed to the weather, and were then weighed again. All had lost in weight, though it is probable that the dry piece had been abraded and its loss was partly

## MEDIUM, DRY, & WET CONCRETE COMPARED.— TABULATION OF DATA & RESULTS.

| Experiment of Mr. Irving Hitz, 10-17-1900 | | | | | Data & Results | Experiment of Parkhurst & Hadsall, 1-19-1901 to 11-18-1901. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Remarks. | *1- Dry | | *2- Wet. | | Materials Used | *1 Medium | | | *2 - Dry | | | *3 Wet | | | Remarks. |
| | Volumes. | | Volumes. | | (Names of) | Volumes, Weights. | | | Volumes, Weights | | | Volumes, Weights | | | |
| | No. | C.Ft. | No. | C.Ft. | | No. | C.Ft. | LBS. | No. | C.Ft. | LBS. | No. | C.Ft. | LBS. | |
| | 1 | 4.71 | 1 | 5.35 | Portland Cement | 1 | 4.42 | 382.5 | 1 | 4.42 | 392.5 | 1 | 4.42 | 382.0 | Method of Mixing and use of the Water in:— |
| | 2 | | 2 | | Sand | 2 | 8.84 | 895.0 | 2 | 8.84 | 908.0 | 2 | 8.84 | 908.0 | Mortar, Stone, Mixt'r. |
| | 5 | 15.25 | 5 | 17.32 | Gravel | 2.5 | 11.05 | 1078.5 | 2.5 | 11.05 | 1104.0 | 2.5 | 11.05 | 1059.0 | |
| | | 17.16 | | 19.50 | Crushed Stone | 2.5 | 11.05 | 915.5 | 2.5 | 11.05 | 9390 | 2.5 | 11.05 | 919.0 | No 1 - 86% 14% 0% |
| | 8 | 37.12 | 8 | 42.17 | Totals | 8 | 35.36 | 3271.5 | 8 | 35.36 | 3343.5 | 8 | 35.36 | 32680 | No 2: 70% 10% 20% |
| | .44 | 2.05 | .82 | 4.38 | Water | 0.6 | 2.65 | 166.0 | 0.41 | 1.81 | 113.0 | 0.76 | 3.35 | 209.5 | |
| | 8.44 | 39.17 | 8.82 | 46.55 | Grand Totals | 8.6 | 38.01 | 3,437.5 | 8.41 | 37.17 | 3,446.5 | 8.76 | 38.71 | 3447.5 | No 3 - 89% 11% 0% |
| | | | | | Temperature | 19°F. to 24°F. | | | 29°F. to 31°F. | | | 31°F. | | | *1 in A.M. *2-3 in P.M. |
| | 35 Min. | | 20 Min. | | Time of Mixing | 21 Min. | | | 25 Min. | | | 23 Min. | | | No.2 was rammed most |
| | 27.00 C.Ft. | | 27.00 C.Ft. | | Volume of Concrete | 22.87 C.Ft. | | | 25.31 C.Ft. | | | 23.06 C.Ft. | | | Freezing slightly at first, 56°F. at 24 hrs. Ago. |
| | | | | | " After 24 hrs. | 22.69 " " | | | 25.31 " " | | | 22.97 " " | | | |
| | 31.1 % | | 42.0 % | | Shrinkage on Total Inc. Water | 40.3 % | | | 32.0 % | | | 40.7 % | | | |
| | 27.3 % | | 36.0 % | | Shrinkage on the Solids only | 35.9 % | | | 28.5 % | | | 35.0 % | | | |
| | | | | | Wght. per cubic ft. (After 24 Hrs.) | 151.5 Lbs. | | | 136.2 LBS. | | | 151.4 LBS. | | | |
| | | | | | Weight 5-11-01. | 3,336.0 Lbs. | | | 3397.0 LBS. | | | 3,350.0 LBS. | | | Cubes Exposed to the weather, No 2 Lost a few Friable Fragments, probably |
| | | | | | Loss in 4 Months | 101.5 " | | | 49.5 " | | | 127.5 " | | | |
| | | | | | Orig. Weight of Water | 166.0 Lbs | | | 1130 Lbs. | | | 2095 LBS | | | |
| | | | | | Water retained | 65.5* | | | 635* | | | 820* | | | |
| | | | | | Weight per cubic ft. | 147.02 Lbs. | | | 134.5 Lbs. | | | 145.84 LBS. | | | (Allow .066. Ft Waste on No 2.) |
| | | | | | Weight 11-18-01 | 3,335.0 Lbs. | | | 3,370.0 Lbs. | | | 3,342.0 LBS | | | |
| | | | | | Loss in 6 Months | 1.0 " | | | 27.0 " | | | 8.0 " | | | Loss on No 2 From Lossening of Gravel Etc. Friable. |
| | | | | | Weight per cubic ft. | 146.98 Lbs. | | | 134.5 Lbs. | | | 145.49 LBS. | | | |

from that cause and partly from loss of water. The wet block had lost most weight; probably, therefore, had lost more water. It should be explained that the blocks stood where passersby may have broken pieces from them, but their general condition was such that the loss in weight was mostly due to actual loss in water, at least for blocks No. 1 and No. 3. This is the more probable, as the weights at the end of ten months varied so little from those at the end of four months. At the end of ten months the blocks were broken, as before stated, and photographs were made, from which the illustratons are made. The texture of blocks No. 1 and No. 3 is excellent, while that of block No. 2 (the dry one) is poor, not well compacted, and the surface is more easily abraded. Before breaking, the blocks were again weighed, results being given in the table.

It will be noted that the weight per cubic foot of the medium block is somewhat greater (1 per cent) than that of the wet one, although the latter had originally—and retained—the more water.

From the foregoing experiment, it may therefore be safely inferred

1st. that a medium concrete, or one that has not enough surplus water to produce quaking, while having enough to permit easy and thorough ramming, is most desirable. The specification that the concrete shall not quake in the barrow, nor while handling, but that it may be wet enough to quake when heavily rammed, would seem about right for regulating the amount of water to be used.

2nd. It is probably safer to have an excess than to permit a deficiency of water. Above all, however, it is of the utmost importance that the concrete shall be consolidated thoroughly by ramming.

## DISCUSSION.

*Mr. Seddon*—I do not feel that I am an authority on concrete, and yet I have a decided prejudice against the word concrete. I did not have time to read Mr. Parkhurst's paper carefully, but from the glance I gave to it, it seemed to me he ought to have changed the title a little—that the real question he has solved is that concrete can be mixed too dry. We all know that and the fact that the medium mixture is better than having it too dry. I should not be at all surprised myself if a concrete mixed to a consistency between the medium and dry would have given a better result than either. The tendency is to mix too wet. It is a temptation to do so all the time. Then, when it is dry, it takes a good deal of ramming to get it in place. I think I shall have to remain a "doubting Thomas" until I see something between the 4.9 and 7 per cent and see that it is worse than the medium. I think the nearer approach you get to a dry concrete that is not *too* dry, the better will be the final result.

*Mr. Parkhurst*—I would like to ask Mr. Seddon what means he thinks we can adopt to get this right stage of dryness. I have described the dry block as made of mealy mixture in order to give some sort of an idea of what that means. The general understanding is that briquets made of a mixture that is damp—that feels damp to the fingers but still not capable of being compacted together in any way without heavy ramming—are the strongest. I think there is no denial of that fact. Probably we might find something between the medium and dry concrete that would be stronger than either, but how shall we define it? How shall we gauge our material so as to get the right result? The suggestion given that the material should be wet enough so that it may be barely brought to the point of quaking when heavily rammed is a pretty definite point. Any gang of concrete men that have made a good deal of concrete can very readily determine where that point is, and can produce a uniform result. To make it dryer than that, it is pretty hard work to gauge your materials and your water to do it.

*Mr. L. E. Cooley*—What per cent of water by weight will produce that condition you speak of?

*Mr. Parkhurst*—Seven and one-half per cent of water by weight.

*Mr. Cooley*—What mixture became the most dense?

*Mr. Parkhurst*—The medium was 1 per cent more dense than the wet. The specific gravity of the mixture is given in the table. At the end of ten months the medium concrete was 146.98 pounds to the cubic foot and the wet one was 145.49—almost exactly 1 per cent less than the dry.

*Mr. Cooley*—What do you consider to be the best size stone for heavy ramming?

*Mr. Parkhurst*—I would prefer to have it 2 inches in its largest dimensions. It is almost impossible to get it that way. We are limited by a good many conditions. In our own practice we have to furnish a great deal of crushed stone in order to get any concrete at all. That has to be gotten from our ballast crushers, and they are set to give certain grades of stone. In certain crushers for ballast work those grades of stone are kept separate. We have a No. 1 (coarse), No. 2 (medium), and then the screenings. In that way we get a good many stones that will have dimensions from 3 inches to 4 inches perhaps in the extreme length. If the proportion of them is very large I have insisted that they shall be broken up by hand or else rejected.

*Mr. Cooley*—I have made specifications that they shall not be larger than 1 inch.

*Mr. Parkhurst*—I think that is in the right direction. It is doubtful whether the result would justify the expense. If we get a fair proportion of finer material from the crusher, and where we use 2, 2½ or 3 parts of sand, as we do in a great many of the mixtures, we can get a concrete that will compact thoroughly without an extraordinary amount of ramming, and have all the voids filled with the mixture and without stratification.

*Mr. Finley*—In a discussion of concrete which occurred before the Society in 1896, Mr. Noble opened the discussion and quoted from a number of authors, both American and foreign. In his conclusion he says: "It thus appears that while there is considerable diversity of opinion as to the exact degree of wetness concrete should have, none of the engineers quoted advised such dry mixtures as are commonly required here. The writer believes that a more homogeneous, a denser, and stronger material will be obtained if the concrete is made so wet that the mass will quake after ramming; and, furthermore, that where concrete is to be placed in contracted spaces, as between timbers, it may be with advantage made still wetter, so that it can be pushed into place with the shovel and, by treading, filling all the spaces solidly, with no important diminution of strength at any point, but stronger as a whole."

*Mr. Parkhurst*—I think that the idea behind Mr. Noble's statement is entirely correct and I would not criticise it at all. The point he makes is that in putting concrete into contracted spaces it must be pretty wet to get it in, and then you must ram it sufficiently to compact it. If you ram it thoroughly you will bring the surplus water to the top, and your concrete will then be in the condition of the wet block, which is only 1 per cent less in specific gravity than the dense one, and if you get that kind of material it is very much better than to have a concrete containing a lot of holes that are not filled with mortar.

*Mr. E. E. R. Tratman*—I think the gist of Mr. Parkhurst's paper is in his last sentence, "It is of the utmost importance that the concrete shall be consolidated thoroughly by ramming." If it is very wet you cannot ram it properly, as the ramming will tend to separate the ingredients; and if it is too dry, no reasonable amount of ramming will fill the voids so as to make a solid and homogeneous mass. You want to have what Mr. Parkhurst calls medium concrete. You can ram it sufficiently to consolidate it, and at the same time fill all the voids, which you cannot do with concrete that is very wet or very dry.

*Mr. Finley*—I think there would be no disputing the fact that concrete may be too dry and also too wet.

*Mr. Parkhurst*—There are other objections to having concrete too wet, aside from the mere fact of not being able to ram it. For instance, a large percentage of it would be spilled in handling it with wheel-barrows. It is my impression that that is very often overlooked. The laborer would rather handle it pretty wet, because it doesn't need as much ramming, and it will tip out of his barrow easily. You have to keep after them all the while in order to make them produce a concrete that is anywhere near dry. On the other hand I think it can be too dry, but it must be made wet enough so that it can be thoroughly compacted by ramming.

I would like to call attention to the statement in the tabulation, of the time spent in ramming the concrete in these three blocks. If we had tamped the wet concrete more thoroughly and spent more time on it, it is quite likely we might have made a more dense block with greater specific gravity, but the object was to do it in as nearly as possible the way men will ordinarily handle it. The actual time spent in handling the wet concrete was a little more than in handling the medium, and the time spent in handling the dry was only two minutes more than in handling the wet, so you will see there is very little difference.

*Mr. Reichmann*—I noticed one point, and that is with reference to change in volume. In the medium concrete the volume changed from 22.87 to 22.69 and in the dry there was practically no change in volume; in the wet there was quite a little change. I think that is a very important feature, especially in building large structures. Where there is a large change of volume I think there would be quite a large internal stress in the concrete after it hardened, and that might produce cracks.

*Mr. Parkhurst*—I think Mr. Reichmann has misunderstood the meaning of the statement in the table. As soon as the cubes were completed they were measured. The change in volume was simply due to the difference in the level of the surface of the concrete on account of the water. There was no shrinkage; it was simply the disappearance of so much water. The second set of figures given in the table are more accurate, the measurement being taken after the water disappeared.

*Mr. Condron*—I wish to ask a question regarding cement of those present who have had experience. Should cement be rejected that fails to stand an eight-hour boiling test? A good many specifications call for the "soundness" test in connection with cement. Some cements that will stand all the other laboratory tests will not stand the so-called "soundness" test. The briquets will go to pieces when they are boiled or when they are held in steam over boiling water. There seems to be a great difference of opinion as to the necessity for having the boiling test for cement. Of course, the object of the test is to show whether there is free lime present in the cement or not, and whether it would be liable to disintegrate and expand after it is in the work. I should like to hear an expression from Mr. Parkhurst as to his experience and whether he makes any use of the boiling test in testing his cement.

*Mr. Parkhurst*—We invariably use it. I think that, as Mr. Condron states, it is not the practice now to place as much stress on that as it used to be, but it is certainly a very desirable test. We had a little experience, some five or six years ago, in connection with work on the lake front retaining wall. A carload of cement was sent to the work and put into it without having been tested. It happened to be put into a piece of foundation work, and for some reason the upper work was not built, and the foundation was left exposed for a week or so. During that time it cracked open a good deal the way silt does when exposed, and the whole concrete broke up into slivers and shells. The only possible reason was that the material had been sent out from the mill before it had been cured. It had been ground and shipped without any storage, etc. If we had tested that cement before it was put into the work, we could very soon have determined what was the trouble, and such an experience would have been entirely prevented if it had been found that the tested cement refused to stand the hot-water test.

*Mr. Finley*—I have been long of the opinion that wet concrete, that does not require much ramming, is likely, when it dries out, to set up, as Mr. Reichmann mentions, internal stresses that are likely to produce cracks. In other words, is not much of the cracking due more to the internal stresses in the concrete than to any other cause?

*Mr. Parkhurst*—I hardly think so. I have not seen anything that would support that theory. We have had occasion to cut to pieces foundations that have been put up both ways—some dry and some wet—and so far as I have been able to see, the cracks seemed to be due to bad foundations rather than any internal stresses. We built under the head house of the Illinois Central certain columns which rest on pile foundations. To protect those columns we built concrete walls, connecting one column with the adjacent one between tracks, the walls being 4½ to 5 feet above the ground and extending down into the ground 2 or 3 feet. We trusted to luck with these foundations. They were simply for protection. The ground had been solid three or four years before, but it was all dug up when the building was constructed, and since then it had not been thoroughly compacted. We built those walls with crushed granite and crushed limestones—fine material, using, I think, in some cases no sand at all, and then putting a layer of mortar on the outside as quickly as possible after the moulds could be removed and before the concrete had really set; the walls had long, irregular, vertical cracks in a good many places. This was evidently due to bad foundations and was not a case of internal stress. We have had occasion to cut those walls to pieces lately, and the interior workmanship was in excellent shape. In some other cases I have had occasion to cut walls through in that way, and in cases of wet concrete we can always see that the material is very well compacted. I think, as a general proposition, that any one who would examine these pieces of work would be in favor of using wet concrete, but I also think they could get a better result by not using it so very wet. I know of cases where it was used very wet and where the results were very satisfactory. The crystallization, as I understand it, takes place all through the mass and is not localized by the presence of water in one place and the absence of it in another, but it is a process that proceeds somewhat slowly and is very uniform.

*Mr. Geo. H. Bremner*—I would like to ask Mr. Parkhurst if, in his experience, he has found that different proportions of water are required for different brands of cement?

*Mr Parkhurst* In making briquets it is quite necessary to proportion the water for the different brands of cement, but in practical work I do not think there is any measure actually made of it, so no one could tell definitely. The foreman gauges the water by the result he gets, and the inspector is chasing him up always to see that he doesn't get too much water. There is no means of measuring. It is generally put on by means of a sprinkling can.

*Mr. Bremner* -You measure it by the quaking of the concrete after it is tamped. Do you put in more water for one brand of cement than for another?

*Mr. Parkhurst* -No. You have to watch the workmen very closely, as they will make it too wet almost invariably.

*Mr. M. K. Trumbull* I would like to ask Mr. Parkhurst if he makes any different specification for his finished coping than he does for the main body of the concrete?

*Mr. Parkhurst*—All finished work is made with the mortar face. The specification is that it shall be 1 ½ inches thick and determined by means of a movable mould. It should be dry enough so that when the mould is pulled out you may tamp the whole of it and have a uniform mortar.

*Mr. J. W. Schaub*—I understood Mr. Parkhurst to say that there is no danger from shrinkage cracks.

In a wall that was recently built, in which the cross-section of the wall was irregular, at intervals of about 24 feet, equal to the spacing of locomotive doors, we noticed shrinkage cracks at regular intervals where the cross-section of the walls was diminished. They were not due to temperature. Later we saw the same thing in another building. It made no material difference in the foundation, however. But on the finished walls, where the wall was exposed, we provide expansion joints to take care of just such contingencies.

*Mr. Parkhurst* I did not mean to say that the material would not shrink. I said I had never noticed any shrinkage due to the use of a smaller or larger amount of water. I think it would be pretty hard to say that the shrinkage which Mr. Schaub noticed was not due to some slight change in temperature.

*Mr. Schaub*—There could not have been more than 10 or 15 degrees change in temperature.

These cracks occurred before there was any load on the foundation, so it was not due to the foundation. When the foundation was fully loaded there was no change whatever.

*Mr. Parkhurst*—I understand that on the drainage canal there is a good deal of concrete, and that no expansion joints were provided. I would be glad to know if any cracks developed.

*Mr. L. K. Sherman*—There were none provided, but I think they were undoubtedly needed to preserve the top coping. That cracked, but I do not think the cracks extend very deep in the concrete.

*Mr. Cooley*—I would like to ask Mr. Parkhurst with reference to the seasoning of a concrete wall 30 or 40 feet thick.

*Mr. Parkhurst*—My experience has not yet extended to that thickness. I do not remember that we have as yet built anything more than 6, 8 or 10 feet thick, and those are cases of where the back of the wall is not accessible, and it is very hard to see just what has happened. I do not think there is anything of a dangerous nature to be anticipated. We have always filled up behind a wall, where it is a big abutment, as quickly as possible and completed our work, and it is impossible to tell just what has happened.

I have nothing to suggest, judging from my small experience, but I should think it might be worth while to keep the outside wall very thoroughly protected from unusual heat or cold. I think cracks might develop on the outside from the fact that the inside had not been properly seasoned, and that there would be some shrinkage in a wall of that thickness. The general effect would be to dry out on the outside.

*Mr. Cooley*—Have you the idea that the inside of that wall will eventually season?

*Mr. Parkhurst*—I remember that Major Marshall said he had taken pains in a number of heavy walls to make a hole in the masonry, which he kept filled with water in order to insure that there should be sufficient water to make the cement set in the interior of the mass, and after several days the water would be absorbed; when no more water would be absorbed he would fill up the holes with concrete. In one or two cases I have made some attempts to follow out that practice, and found the water was not absorbed at all; that the cement seemed to take all that it wanted at the outset, and judging from the way these three blocks of concrete acted, no more water was needed.

*Mr. Condon*—Possibly Major Marshall had more voids in his concrete.

*Mr. Wm. Seafert*—Didn't Major Marshall use natural cement?

*Mr. Roberts*—I would like to ask Mr. Parkhurst how often, in a continuous wall of considerable length, he would consider it necessary to provide the expansion joints referred to, and in what manner he constructs them.

*Mr. Parkhurst*—I will say that we have not built anything of that kind in that way, but I have considered the subject and made up my mind that somewhere from 20 to 30 feet is about the proper distance for expansion joints.

In the wall on the west side of our tracks, just north of the Central Station building, there were three sections of concrete built, making about 100 feet in length, and there were pilasters built at every 33 feet. Three sets of artificial joints were made, adjacent to the pilasters in each case, and I have been watching this from time to time. The artificial joints were made simply by putting a septum in the wooden mould in which the concrete was built and building up to that, then taking that away and building the next section. In extreme cold weather these joints open $\frac{1}{16}$ inch. They were built at a temperature of 50 to 60 degrees, and we have had temperature down as low as 14 to 20 degrees below zero. I have watched them in cases where the temperature was quite low to see what the crack would be, and it was nearly $\frac{1}{16}$ inch.

*Mr. Cooley*—Was there no indication of cracks elsewhere?

*Mr. Parkhurst*—No. One trouble is, if the wall is built in cold weather you have nothing to provide for the expansion, and just what would happen under these conditions I do not know. I am inclined to think that in a long wall there would be some bad breaks, but in a short stretch there is no difficulty.

*Mr. Cooley*—What has been your experience in using metal to provide expansion joints?

*Mr. Parkhurst*—I do not think you could do it. The metal would either have to be provided with expansion joints or else there would be a large crack in a long wall. I should prefer to design the structure with an expansion joint.

*Mr. Finley*—I examined a number of concrete abutments built last summer, and some of the abutments were provided with indentations in them, made by putting a triangular piece in the mould, and I noticed that the cracks occurred at these indentations, while the abutments that had no such indentations had cracks just the same, and were of course much more noticeable.

*Mr. Roemheld*—There are some very beautiful specimens of what is represented to be artificial stone on the table. May we not hear something about them?

*Mr. Stevens*—They are all made without pressure and the concrete part is made without tamping. The sand and cement are first put in place and then the stone thrown into it, and it settles to its place as you see it in the sample.

*Mr. Seafert*—The materials are mixed very wet, the fluid about the consistency of paint as applied with a brush—one part cement to three of stone crushed to a uniform grain. The mixture is then poured from a bucket or other vessel, depending upon the size of the stone to be cast. During the pouring process the fluid mixture is continually stirred with a stick or paddle. A sand mould similar to the moulds used in casting iron is used. The sand receives the impression of a wooden or iron pattern. The pouring process is all the labor required in forming this stone, no tamping being done. The stone remains in the mould from twenty-four to thirty-six hours, when it is removed, and brushed to get rid of the adhering sand, when it shows all of the delicate lines and tracings of the most intricate pattern. The structure of the mass of the stone is absolutely dense and homogeneous, and one peculiarity of this process is that the knife edges of carvings or petals of flowers come out as dense and hard as the body of the stone and plain surfaces. It is a well-known fact that tamped concrete is always brittle where fine, sharp edges form part of the work, in imitation of carved stone.

This stone can be tooled and worked when green with great ease, giving an exact imitation of the natural stone, and it can likewise be turned on a lathe. It is extensively used in this way for columns and other forms in buildings, resulting in a great saving in the cost over the price of natural stone.

*Mr. Finley*—Are the moulded fronts tooled afterwards?

*Mr. Seafert*—No, they are tooled in the yard.

*Mr. Finley*—Are these made in one piece and set up?

*Mr. Seafert*—They are made at the factory in Harvey and delivered in any size. They simply run the material in the sand mould to the length desired, and before it is dry it is cut. The stone has been made into belt courses 100 feet in length. Crushed stone is preferred to sand for producing fine work. The object of the sand mould is to take up the surplus water.

*Mr. Finley*—How about the cost?

*Mr. Stevens*—It is much cheaper than stone. Of course, there is more difference in ornamental work than plain.

## CXLVI.

# MECHANICAL DRAFT.

By Mr. F. R. Still, Detroit, Mich.

*Read March 19, 1902.*

A question most frequently put to us is this: "What is the gain or economy of mechanical draft over chimney draft, if the chimney furnishes all the draft required, when fuel economizers are not employed?" To attempt to convince the commercial end of an institution that there *is* a gain is quite a task, as you will seldom find a man of this kind who believes that "figures don't lie." You begin talking density, heat units, specific gravity, carbonic acid gas, etc. He at once becomes incredulous. There really is not much gain, if the conditions for chimney draft are perfect, but this is seldom found. There are three prominent factors that make the fan more economical in comparison:

1. Less air is required per pound of coal.
2. A cheaper quality of coal can be burned.
3. Less heat is required to produce the draft.

We will take up each of these in order for further explanation, as follows:

1. For hand firing with natural draft about 24 pounds of air per pound of ordinary coal is usually required, whereas only 18 pounds or less is required with mechanical draft. Thus the direct saving is due to the heat required to raise 6 pounds of air per pound of coal from the outside temperature to the temperature of combustion.

2. That cheaper fuel can be burned is a point too well understood to need enlargement here; suffice it to say that the price of coal is often cut in two.

3. The amount of heat required to produce a given draft by a chimney can be quite clearly arrived at; but how much coal is burned to produce this required temperature or heat, over and above what is otherwise actually consumed by evaporation and radiation from the boiler settings and connections, cannot be so easily ascertained. We all know that the evaporative efficiency of a boiler varies with every change in quality of fuel. This variation, however, does not bear a direct ratio to the heat units in the coal, the loss being greater as the quality of coal is poorer. This latter is directly due to the fact that a poor quality of coal requires a stronger draft to draw the required volume of air through the grates for combustion. The height of the chimney being fixed, an increased draft can only be secured by a higher flue temperature.

which, of course, means burning more coal than is actually necessary for the other requirements of the plant. But there is a limit to which this can be carried. We can approximately determine the saving by an example:

Supposing we have a plant of 1,000 h.-p. rated capacity in water tube boilers; the grate area being 280 square feet; the steam pressure, 125 pounds; temperature of feed water, 212°; diameter of stack, 72 inches; height of stack, 150 feet; temperature of outside air, 62°; temperature of flue gases, 500°. The coal, we will assume, is a good quality of Pittsburg or Virginia coal, having about 14,000 B. T. U. per pound. The maximum evaporative capacity will be $\frac{14{,}000}{965.7} = 14.5$ pounds of water per pound of coal. Assuming the boiler efficiency as 70 per cent, the actual evaporation will be 14.5 x .70 = 10.15 pounds.

$$\begin{array}{lr} \text{The heat in steam at 125 pounds} & = 1189.5 \text{ H.U.} \\ \text{The heat in water at } 212^\circ \text{ F.} & = \phantom{0}180.9 \text{ H.U.} \\ \hline & 1008.6 \text{ H.U.} \end{array}$$

One horse-power equals 33,305 B. T. U., which, divided by the above, gives 33.02 pounds of water per h.-p. hour. Thus, 1,000 h.-p. x 33.02 pounds equals 33,020 pounds of water, divided by 10.15 pounds evaporated per pound of coal equals 3,253 pounds of coal per hour, or 3¼ pounds per h.-p. hour.

The maximum draft produced by the chimney will amount to

$$P = h\,(d - d,) = 150\,(.076097 - .041414) =$$

5.2 pounds per square foot, or 1 inch W.G.

The friction of the chimney would amount to about ¼ pound per square foot, or 0.05 inch W.G., leaving the draft practically 0.95 inch W.G.

The height of a column of external air which will produce the above pressure per square foot is—

$$H = h( \frac{(d - d,)}{d} = 150 \frac{(.0761 - .0414)}{.0761} = 68.5 \text{ feet.}$$

The velocity due to this head is—

$$V = \sqrt{2gH} = \sqrt{64.32 \times 68.5} = 66.37 \text{ feet}$$

per second, and its weight

$$66.37 \text{ ft.} \times 28.27 \text{ sq. ft. (area of stack)} \times .0761 \text{ lbs.} = 142.8 \text{ pounds.}$$

The movement of air is due to heating it from 62° to 500°, or through 438° F. The heat required to move the air is—

$$142.8 \text{ lbs.} \times 438^\circ \times 0.2375 = 14.850 \text{ B. T. U.}$$

As one heat unit is equivalent to 778 foot-pounds of work, this heat amounts to 14,850 x 778   11,550,000 foot-pounds. But the work actually done is in overcoming the pressure over the entire area of the chimney, amounting to 28.27 sq. ft. x 5.2 = 147 pounds through a space of 66.37 feet, or 9,855 foot-pounds. Therefore, the efficiency of the chimney is

$$\frac{9{,}855}{11{,}550{,}000} = 0.000{,}845 = (\frac{8}{100} \text{ of } 1\%)$$

If a fan be substituted for the chimney, and we allow, say, 7 per cent for the efficiency of the boiler and engine, 40 per cent for the efficiency of the fan, and deduct 20 per cent for friction, we will have as the combined efficiency

$$0.07 \times 0.4 \times 0.8 = 0.0224, \text{ or}$$

about 2¼ per cent efficiency.

Dividing this latter by the efficiency of the chimney (0.000845) shows the fan to be 26½ times more efficient than a chimney, under exactly similar conditions, when assuming the engine and fan efficiencies at extremely conservative figures.

It is customary to guarantee that the power expended in driving a fan will not exceed 2 per cent of the steaming capacity of the plant, and it always falls below that with anything like normal proportions. With this 1,000 h.-p. plant, 2 per cent would equal 20 h.-p., or 660,000 foot-pounds. Thus the chimney would require 17½ times more heat than the fan, by this rough approximation—

$$\frac{11{,}500{,}000}{660{,}000} = 17\tfrac{1}{2}.$$

Now, if we introduce fuel economizers for abstracting part of the heat from the flue gases, what will be the result? Of course, the temperature of the chimney will be lowered, also the draft. We will assume that the temperature will drop from 500° to 280°. At this latter temperature the draft will amount to 4.425 pounds per square foot, or 0.85 inch W. G. maximum, or about 0.8 inch W. G., deducting the friction. In order to produce the same draft as in the previous instance where the temperature was 500° we would have to add 26 feet to the height of the chimney. If a draft of one inch was necessary in one case, it must be necessary in the other; so, if it is intended to put in economizers at any time, the chimney must be designed for it. This does not apply to fans, as will be shown later.

But to get back to the point under consideration, it was noted above that the chimney would have to be 176 feet high if the same draft was required as before. The velocity due to this head is 57.72 feet per second, and its weight per second is 57.72 x 28.27 sq. ft. x 0.0761, which equals 124 pounds. This has been moved through 218°, requiring 6,426 B.T.U., or 5,000,000 foot-pounds. The work actually done at this temperature is 4.425 lbs. x 28.27 sq. ft. x 57.72 ft. per second, which equals 7,224 foot-pounds. Thus the efficiency in this case is 0.00144, or $\frac{14}{100}$ of 1 per cent. On this basis the chimney still requires 18½ times more heat than the fan, on the most conservative estimate possible, not taking into account the reduction in power required by the fan owing to the lowering of the temperature of the gases. This difference would more than off-set the difference just mentioned as compared with the previous case.

Before we drop this suppositious case, let us suppose again that the chimney was built 150 feet high and could not be added onto later, when the economizers were installed. If we originally needed one inch draft — and we surely would, if we ever did, after adding the economizers — the only way to get it would practically be to raise the flue temperature just as much higher as the natural drop would be, due to the heat absorbed by the economizers, or 220°, making the relative flue temperature 720°. If we add this heat loss, the efficiency of the chimney will drop to 0.00057, or less than $\frac{6}{100}$ of 1 per cent. Thus —

142.8 lbs. x (720° — 62°) x 0.2375 = 22,300 B.T.U. x 778 = 17,320,000 ft.-lbs.
and 9855 ÷ 17,320,000 = 0.00057.

Thus the chimney would require 39½ times the heat required by the fan. In the above no account has been taken of the difference in the amount of air required by chimney or fan draft.

As 3,250 pounds of coal will be burned per hour, the fan requiring 6 pounds less air per pound of coal than the chimney, will represent a further saving of about 3 per cent, the fan being 27¼ times more efficient.

$(500° - 62°) \times (\frac{3250 \times 6}{60}) \times 0.2375 = 33{,}800$ H. U. x 778 = 26,250,000 ft.-lbs. per minute ÷ 60 = 437,500 ft.-lbs. per second + 11,550,000 ft.-lbs. = 11,987,500.

$\frac{9855}{11{,}987{,}500} = 0.000824$, efficiency of chimney. Thus the engine is
0.0224 ÷ 0.000824 = 27¼ times more efficient than chimney.

The question naturally arises, "Why is less air required with a fan than with a chimney?" I will explain by stating that, while a fan may be designed for, say, one inch draft, if resistance is offered to the flow of the air either at the outlet or inlet the pressure or vacuum will quickly run up to over three times that amount without increasing the power required to drive the fan, as, in fact, it reduces the power, as will later be shown.

Therefore, with a force which is sufficient to overcome almost any furnace resistance regardless of any reasonable thickness of fire or temperature of flue gases, the required volume of air is always assured. Consequently a thicker fire can be carried without there being the patches always present in natural draft furnaces, through which large volumes of air escape, and for which provision has to be made in calculating the quantity of air necessary.

This same explanation applies to the burning of cheap fuel. All kinds of cheap coal cannot be burned. What is generally termed "cheap coal" is the screenings or slack from a good quality of lump or anthracite coal, and is sold at about half the price. It usually requires a much stronger draft than can be produced by a chimney of any reasonable height, and is most successfully burned with automatic stokers, although it can be burned in a properly designed furnace using natural draft, wherever the boilers are not worked very hard. The draft required for the efficient combustion of most fuels is quite accurately determined and has been tabulated by Dr. R. H. Thurston, as follows:

| | | |
|---|---|---|
| Straw | 0.20 | inches W.G. |
| Wood | 0.30 | " " |
| Sawdust | 0.35 | " " |
| Peat, light | 0.40 | " " |
| Peat, heavy | 0.50 | " " |
| Ordinary slack | 0.6 to 0.9 | inches W. G. |
| Good steam coal | 0.4 to 0.7 | " " |
| Very fine slack | 0.7 to 1.10 | " " |
| Coaldust | 0.8 to 1.1 | " " |
| Semi-Anthracite | 0.9 to 1.2 | " " |
| Breeze and slack mixed | 1.2 to 1.5 | " " |
| Anthracite slack | 1.3 to 1.8 | " " |

The element of first cost is another point which naturally comes to the surface shortly after introducing the subject.

The foundation for a mechanical draft plant is always cheaper than for a chimney. The larger a boiler plant is, the greater is the proportionate difference in the cost of a chimney and a fan, in favor of the latter. A comparison of a number of plants of 1,000 h.-p. and over shows conclusively that a forced draft plant, with short stack, costs less than 25 per cent of a chimney; a single-fan induced draft plant less than 40 per cent, and a double-fan induced draft plant, with all connections and a short stack, will cost less than 50 per cent of the cost of an ordinary brick chimney. A double-fan system is only advocated when the service is continuous, as in electric light and street railway plants, one fan being held in reserve.

Another item worthy of consideration is the smaller boiler plant required. We do not advocate setting out to over-rate a boiler plant when designing a new one, but it is often of great convenience to do this with an old one, saving a heavy expense for new boilers and sometimes overcomes the necessity of tearing out the entire steam plant and moving to other quarters so as to obtain space for additional capacity required.

Many other reasons can be noted, all going to make up a saving to the purchaser. To attempt to approximate the saving in dollars would be an almost impossible task, involving as it does interest on the investment, insurance, taxes, depreciation, repairs, operating expenses, fuel, labor, transportation charges, etc.

Another important point that, in itself, is frequently a sufficient reason for installing the system, is the so-called "smoke nuisance." With the more rapid and perfect combustion obtained with a fan and a little care exercised in firing, there can be absolutely no excuse for the immense volumes of black smoke emitted by the chimneys of some factories. A mechanical draft plant is not a smoke consumer any more than a very high chimney is, but both are as near being so as most of the devices sold for that purpose. In thickly settled communities, smoky chimneys are often the cause of many manufacturers being defendants in long and very costly lawsuits. We have had several of them in Detroit, and others are to follow.

Another question which is frequently asked is, "What are the relative advantages of forced and induced draft?" For under-feed stokers of the retort type, hollow blast grates, and the closed firehold system generally employed on board ships, forced draft is eminently adapted. But induced draft is the ideal system for all other types of automatic stokers, grates, etc., used with stationary boiler plants.

The superiority of induced draft is very pronounced. The fire will burn evenly all over the grates; there is less trouble from holes or patches burning in spots, as with forced draft unless carefully watched.

It is never necessary to shut off the draft when firing, as there is no pressure in the combustion chamber to force the gases and dust out of the fire doors when opened. The ash pit can be cleaned at any time without shutting off the draft, as the movement of air is inward instead of outward. The ventilation of the boiler room is better, not filling it with smoke and ill-smelling gases. The boiler flues can be kept cleaner. There is less liability of injuring the boiler. Larger fuel economizers can be used, as temperature of the gases can be reduced to a very low point, absorbing very useful heat, without bad effects.

An induced draft plant costs considerably more than forced draft, owing to the difference in the size of the fans, but costs no more to operate. It has every advantage of forced draft in the matter of handling fires and producing steam under adverse circumstances, with none of its disadvantages.

So much for mechanical draft. The next is how to apply it.

Before this can be entered into fully it will be necessary for us

FIG-I.

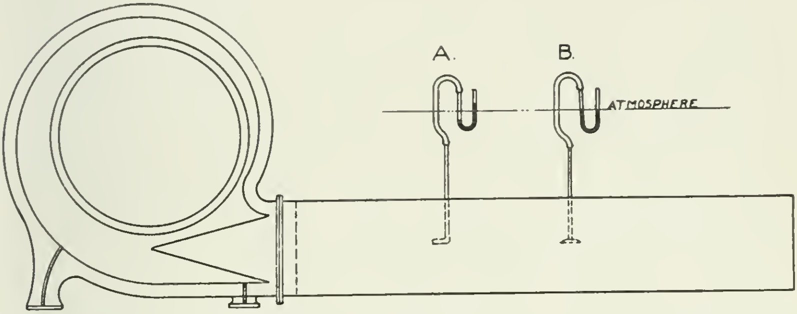


FIG.-II.

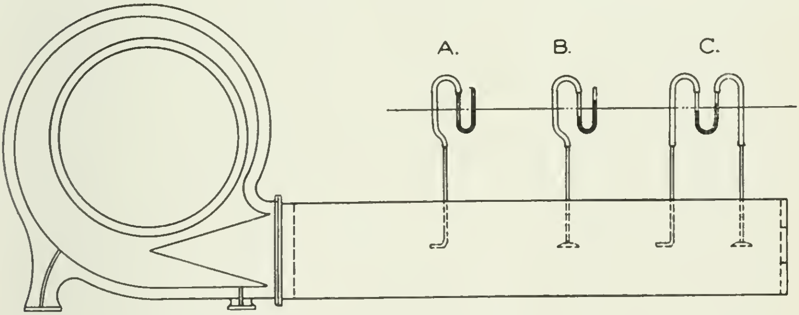
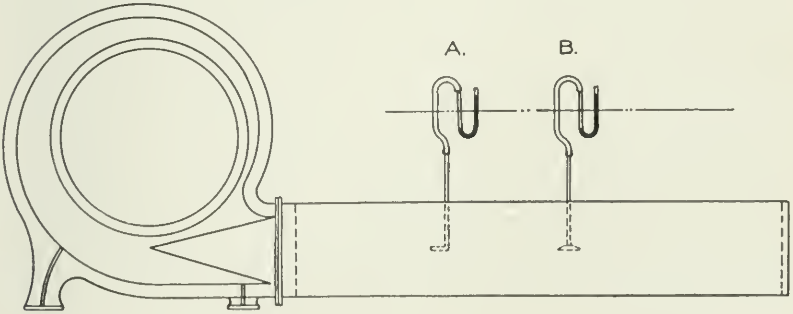


FIG-III.



to arrive at a general understanding of the terms used later on, and to facilitate this some diagrams have been prepared.

The same two forces are at work in the discharge from a blower, as are present in all mechanical problems, namely, "dynamic" and "static" forces, which we will here call "dynamic pressure" and "static pressure." One is always working against the other, with the result of practically producing a third pressure, which, for want of a better term, we will call "air velocity pressure."

The pressure and movement of the air is due entirely to the centrifugal force produced by the air sliding off from the fan blades.

The centrifugal force is in direct ratio to the square of the revolutions. With a fan wheel of given proportions the centrifugal force holds a direct ratio to the peripheral velocity. For comparison, we will create nominally a fourth pressure, which we will call "peripheral velocity pressure," being an assumption that if air was moving at the same velocity as the fan tips a pressure equal to the "peripheral velocity pressure" would be produced.

To illustrate the measurement of the first three pressures we will refer to Figs. I, II and III. We have here a blower discharging into a pipe 6 or 8 feet long, with the usual "U" tube or water gauge for measuring the pressure.

In Fig. I, "A" shows the "dynamic" tube, and "B" the "static" tube. Notice that the dynamic tube is attached to a bent pipe that faces the air current, while the static tube is at right angles to it.

Now, if the end of the pipe is open, as shown, there will be no difference in the level of the water in the two legs of "B," as, there being no resistance to the air current, there is no static pressure. In this case, "A" gives the combined reading of "dynamic pressure" and "velocity pressure."

In Fig. II, a diaphragm has been inserted in the end of the pipe, reducing the area of the outlet, say, 50 per cent. Notice that the water in "A" has risen much higher than in Fig. I, and that there is now a reading in "B" that is almost the same as it was in "A." By deducting the difference between "A" and "B," or rigging up a tube as shown at "C," we get the "velocity pressure," and from which can readily be determined the quantity of air passing through the pipe.

In Fig. III, the discharge pipe has been closed entirely. Now see the effect on the tubes. The water in both of them is higher than at any previous reading, and both are alike.

These are points not fully understood by a great many engineers, and will also explain the capacity tables published by certain blower manufacturers. It is not very long ago when an engineer for one of them asserted with great assurance that the "Pitot tube," which is here called the "dynamic" tube, gave the pressure due to the velocity of the air. Do you wonder at the great difference in the published capacities of the different makers of fans, and the actual results given by test, as doubtless many of you have found by experience? This will also account for the very high mechanical efficiency claimed by some makers.

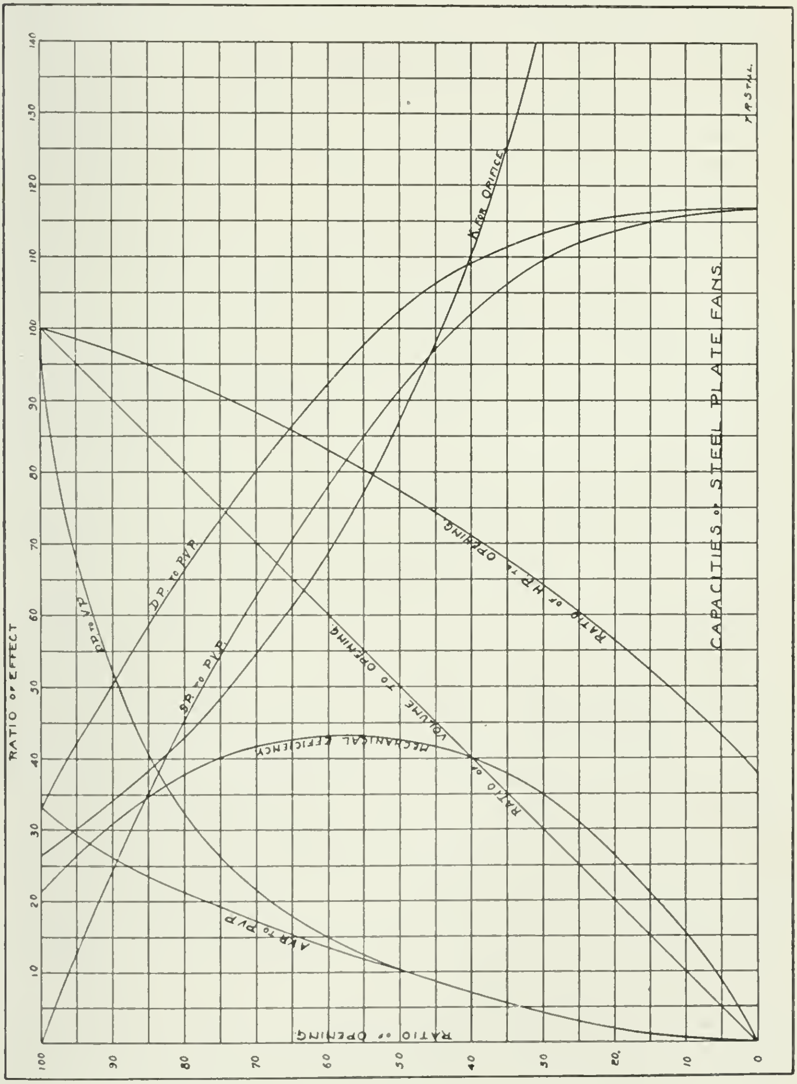


Fig. IV

We will now refer to a diagram, Fig. IV, which shows the relative capacities of fans under different conditions of service. This merely applies to steel plate fans, although the difference is not very great for any type of centrifugal fan.

The length of the fan blades and the speed have more effect than anything else. The longer the fan blades, the greater the centrifugal force at a given speed. Again, the greater the peripheral velocity up to about 6,600 feet per minute the higher is the mechanical efficiency. Above 6,600 feet it begins to fall off very rapidly, much the way it does when the outlet is entirely closed. The "ratio of opening" at the left might be taken as the ratio of resistance. It is the percentage of opening in the discharge as compared with the total discharge area. The "ratio of effect" is the relative effect produced on the different elements of the fan by restricting the discharge.

Supposing we have a fan with an unrestricted inlet and outlet that will deliver 25,000 cubic feet or air per minute at a head of 0.33 inches, with a given peripheral velocity, requiring 6.16 h.-p. If we close the discharge outlet to 50 per cent of the full area it will deliver only 12,500 cubic feet. The pressure will be increased to 1.03 inches, and the power to drive will drop to 4.8 h.-p. If we still further reduce the outlet to 20 per cent of the full area, the capacity will drop to 5,000 cubic feet. The pressure will increase to 1.15 inches, and the power will be decreased to 3.45 h.-p.

To determine exactly how a fan will perform is almost impossible, as all the conditions incident to its installation can never be foreseen. But we can get very close to it, as a rule.

It is customary, when little is known about the plant the fan is going into, to assume that the resistance is equivalent to restricting the discharge outlet 25 per cent. This has always proven sufficient in the average mechanical draft plants we have put in. Some very large plants, with very large economizers, long smoke flues and other obstructions, have to be treated differently, the friction being figured up and added to the velocity head to determine the dynamic pressure.

We will again take up the same 1,000 h.-p. boiler plant previously under discussion, which showed a consumption of 3,253 pounds of coal per hour. Allowing 18 pounds of air per pound of coal, 5 per cent for ash and 5 per cent for leaks, at 500°, the fan will have to handle about 65,000 pounds of gasses per hour, or 27,250 cubic feet per minute.

We want a draft of one inch at the inlet, and having allowed for leaks in the above capacity, we can expect the same at the bridge wall. By adapting Murgue's formulæ for equivalent orifice $A = \frac{K\ Q}{\sqrt{P}}$ to obtain the inlet area, we find on the chart that $K = 0.485$;

A is the area in square feet; Q is the quantity in thousands cubic feet; P is pressure in inches. Thus—

$$\frac{0.485 \times 27.25}{\sqrt{1}} = 13.2 \text{ sq. ft.} = 49\tfrac{1}{4} \text{ inches diameter.}$$

The area of the inlet should not exceed 40 per cent of the area of the side of the wheel. Thus, $\frac{13.2}{0.40}$ = 33 sq. ft. or 66 inches (5 ft. 6 ins.) in diameter.

The velocity due to one inch pressure at 500° is $81.5 \sqrt{1} = 81.5$ feet per second, or 4,890 feet per minute.

Referring to the chart, we find the ratio of dynamic pressure to peripheral velocity pressure is 0.73. Thus the velocity of the fan wheel will be $\frac{1}{0.73}$ = 1.37 inches.

$$81.5 \sqrt{1.37} = 95.5 \text{ ft. per second} \times 60 = 5{,}730 \text{ ft. per minute.}$$

Thus the air velocity is about 85 per cent of the peripheral velocity.

To find the "blast area" of the fan wheel we will proceed as follows: $\frac{27{,}250}{5{,}730}$ = 4.76 sq. ft., or 685 sq. ins. x 3 = 2,055. The constant "3" is an arbitrary one, established by experiment. With a free discharge it is 2.2 on fans of this type. Now, by dividing the product above found by the diameter of the wheel will give the proper width at the periphery. Thus, $\frac{2055}{66}$ = 31.2 inches wide.

From this point different makers have ideas of their own, founded upon no particular reason as regards total width of fan. The only reason for beveling the sides of the fan blades, as is the universal practice, is to give strength and stiffness to the wheel with light material. Being a circular cone, it forms a truss between each blade, much stronger than if the side plates were flat.

The correct principle is to make the circumference at the inlet multiplied by the breadth equal to the circumference at the periphery multiplied by the breadth at that point.

To facilitate manufacture and do away with special patterns, we make the bevel 20°, the tangent of which is 0.3639.

The length of the blades will be 8⅜ inches.

The over-all width at inlet will be 37¼ inches.

The width of the housing will be 38 inches.

As the inlet has 1,900 square inches area, the outlet will be $\frac{1900}{38}$ = 50 inches; that is, 38 inches wide by 50 inches high.

It would be advisable to put on a stack 5 feet in diameter, so as to reduce the resistance as much as possible. The speed of this fan will be

$$\frac{5.730}{5.5 \text{ ft.} \times 3.1416} = 332 \text{ R.P.M.}$$

The power required to drive the fan will be

$$\frac{27{,}350 \times 1 \times 5.2}{33{,}000 \times 0.40} = 10.75 \text{ brake h.-p.,}$$

or a fraction over 1 per cent of the steaming capacity of the plant. If the engine required 50 pounds of steam per h.-p. hour, it would only amount to 538 pounds of steam, or 1⅝ per cent of the evaporating capacity of the boiler.

In closing, a few remarks regarding some of the practical points will be in order.

Avoid, wherever possible, large heavy swinging dampers. Cut them up into small ones, as in a floor register, only not so small; say 12-inch to 20-inch louvers, with a rod connecting the louvers outside, so that they will all operate simultaneously.

Always have a water-jacketed box next to the fan if the gases are very hot. It is unnecessary to water-jacket the engine boxes if they are two feet or more from the fan.

Use 3/16 steel plate or heavier for the fan housing. It is likely to warp badly if any lighter. No. 14 plates can safely be used for the fan blades.

Over-hung wheels generally work in better but give no better satisfaction than a long shaft extending through the inlet chamber with an out-board bearing, on account of the almost inevitable deflection.

See that good-sized man-hole doors are provided in the housing for access to the interior of the fan.

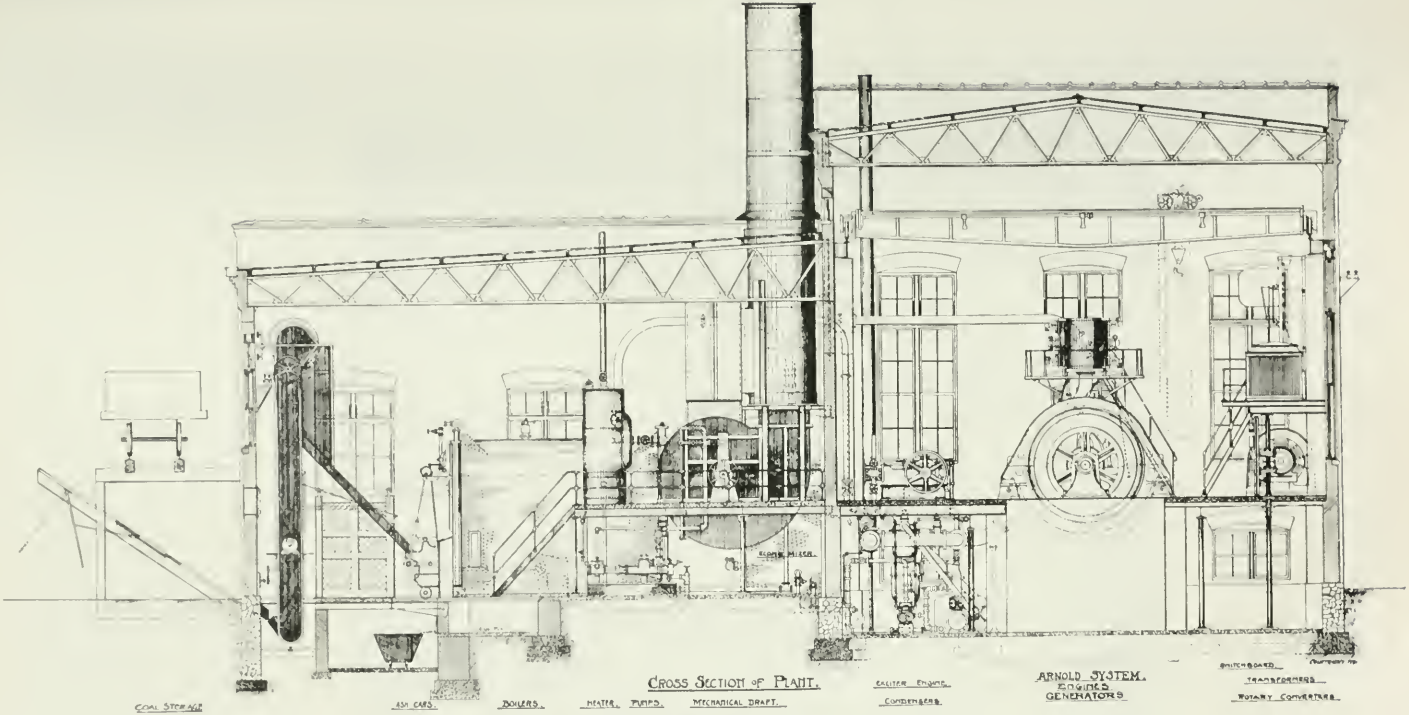
Never support the stack by the fan housing. Carry it on channels or columns from the floor.

Always use an automatic fan engine regulator to automatically control the speed of the fan according to the fluctuations of steam pressure. A good valve will control the pressure without a variation of two pounds.

## DISCUSSION.

*Mr. Damon*—I have here several slides illustrating one of the mechanical draft equipments installed in one of the stations designed and built by the Arnold Electric Power Station Company. This plant is located at Jenison, Michigan, and furnishes power to the Grand Rapids, Holland & Lake Michigan Rapid Railway Company.

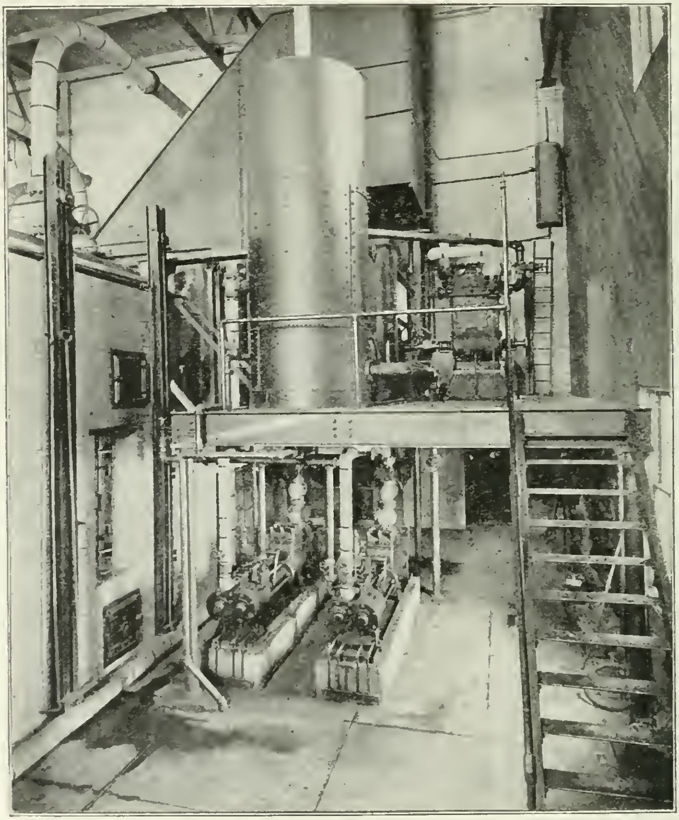
The illustrations show four 250 h.-p. boilers of the Babcock & Wilcox type, with the smoke connection at the back, leading into a short steel breeching, which runs along back of the boilers and discharges directly into the fan intake. The fan is driven by an upright engine and discharges into a stub stack which passes through the roof. In case we do not wish to use the fan, the gases can be passed directly up the stack. At the present time only one fan is in place, and this is located on an iron platform on a level with the engine room floor, so that the engine driving the fan is brought directly under the care of the engineer, but at the same time is not far away from the man running the boiler plant. · The fan is of the



CROSS SECTION OF PLANT.

POWER PLANT
OF THE
GRAND RAPIDS, HOLLAND & LAKE MICHIGAN RAPID RY.
JENISON MICH.
DESIGNED AND BUILT BY THE
ARNOLD ELECTRIC POWER STATION CO.
ENGINEERS AND CONTRACTORS
1510 MARQUETTE BLG
CHICAGO.

three-quarter housing type, and the top of the stack is 40 feet above the grates. By means of the fan engine we ordinarily obtain about ¾ inch of draft, but by speeding the fan up we can get as high as 2 inches. The speed of a fan engine can be controlled by hand with a valve, and there is also an automatic valve connected directly to the steam header, so that immediately when the steam pressure drops, the fan engine is speeded up and the draft is increased and vice versa. When the plant is increased by adding more boilers another fan and direct connected engine will be installed, and both fans connected so that either or both can be used on any one or all the boilers.



Power Plant of G. R., H. & L. M. R. Ry., Jenison. Mich.

Our office has studied over a number of ways of putting in economizers, and the arrangement of this plant is the result of a number of different plans we have tried. The economizer is always a heavy piece of apparatus, and by placing it as low as possible something is saved in supports and cost of installation. Flues and dampers are provided so that gases from the boiler can be either diverted through the economizer or can be by-passed around both the economizer and the fan, and allowed to escape directly up the stack.

The fan and engine cost less than half of the investment required for a self-supporting unlined steel chimney. It has now been in operation for about six months, and the engineer tells us that the equipment gives him less care than any of the apparatus around the plant. The station has not yet been tested, so we have no figures in regard to economy.

*Mr. C. W. Rogers*—I am on the same side as Mr. Still, but my conversion to mechanical draft in practical every-day affairs, I am frank to say, dates back only a few years.

In the Fisher Building, across the street, they have all the draft they want. They have from 1 ¼ to 1 ½ inches in winter time, and I believe they can make as much steam per pound of coal, or can make steam as cheaply as in any building in town. Their smoke stack is about 200 feet high. This city is full of short stacks, 60, 80 or 100 feet high. If a boiler plant of 1,000 h.-p. needs a stack 200 feet high, a boiler plant of 60 h.-p. needs the same height of stack, because the draft depends upon the height, and I believe that there are many small boiler plants with stacks from 60 to 70 feet high that with comparatively slight expense could get the same amount of draft that the tall buildings have. There seems to be an increased call every day for induced draft for small boiler plants. By spending a few hundred dollars and getting the benefit of the 200-foot stack—that is, *getting draft enough*—the fuel bill will be cut down and the smoke nuisance reduced.

I was talking with a gentleman located here in this city, not long ago, who is burning about 500 tons of coal per day, and his conclusion was that you could save dollars down in the fire hole where you can save cents up in the engine room. Also his conclusion was, in regard to different kinds of boilers, that you could get about as good results out of a plain tubular boiler, if it is kept clean and has plenty of draft, that you can out of the best water-tube boiler made. There is a small plant here in this city which is a very good illustration of what can be done in the way of draft. This is the People's Gas Light & Coke Company's plant at Twenty-third street. They have a boiler plant consisting of five plain tubular boilers. The boilers had been run during the summer time with natural gas for fuel. In the fall of 1890 the gas company started to burn coal, with a set of green firemen, with a new installation of induced draft. Complaints were made that the boiler plant was not satisfactory, and the owners called in the Hawley Down-Draft

Furnace Company. Four tests were made during the month of October.

The boilers were tested October 1st. Test was made on No. 1 boiler with induced draft on Riverton pea coal. Duration of test, 8 hours. The result of test was as shown in the first column of Table No. 1:

TABLE NO. 1

| | No. 1 Induced Draft | No. 2 Natural Draft |
|---|---|---|
| Average vacuum | 0.4 in. W.G. | 0.3 in. |
| Total coal consumed | 5,600 lbs. | 5,250 lbs. |
| Coal consumed per hour | 700 lbs. | 656 lbs. |
| Coal per square foot of grate surface | 29 lbs. | 21.8 lbs. |
| Total amount of ash | 1,194 lbs. | 1,056 lbs. |
| Per cent of ash | 21% | 20% |
| Total water evaporated | 37,532 lbs. | 33,276 lbs. |
| Water evaporated per hour | 4,691 lbs. | 3,156 lbs. |
| Water evaporated per pound of coal | 6.70 lbs. | 6.33 lbs. |
| Horse-power | 125 h.-p. | 110 h.-p. |
| Temperature of feed water | 167° F. | 167° F. |
| Average steam pressure | 74 lbs. | 73 lbs. |

A second test was made October 2nd with natural draft, and on Riverton pea coal. Duration of test, 8 hours. The result of this test was as shown in the second column of Table No. 1.

The second test shows but little difference from first test, although the difference is in favor with the induced draft. The advice given to the owners was to give the firemen a chance to get used to the furnaces, and also to give particular attention to the cleaning of the boilers and stopping small leaks around the furnace setting.

On October 26th a third test was made on the same kind of coal. Duration of test, 8 hours. The result was as shown in the first column of Table No. 2.

TABLE NO. 2

| | No. 3 | No. 4 |
|---|---|---|
| Average vacuum | 0.4 in. W.G. | 0.5 in. |
| Total amount of coal consumed | 7,200 lbs. | 7,200 lbs. |
| Coal consumed per hour | 900 lbs. | 900 lbs. |
| Coal per square foot of grate surface | 40 lbs. | 40 lbs. |
| Total amount of ash | 1,125 lbs. | 1,135 lbs. |
| Per cent of ash | 15.6% | 14.3% |
| Total amount of water evaporated | 52,236 lbs. | 54,820 lbs. |
| Water evaporated per hour | 6,529 lbs. | 6,852 lbs. |
| Water evaporated per pound of coal | 7.03 lbs. | 7.75 lbs. |
| Horse-power | 189 h.-p. | 198 h.-p. |
| Temperature of feed water | 166° F. | 161° F. |
| Average steam pressure | 76 lbs. | 77 lbs. |

This test was made by the engineer in charge of the station, Mr. Sweetman. The test showed such marked improvement over test No. 1 that it was questioned by the chief engineer, and test No. 4 was made as a check on test No. 3. This gave the results shown in the second column of Table No. 2.

A comparison of test No. 1 with test No. 2 shows with natural draft the capacity of the boiler to be 110 h.-p., while with test No. 4 its capacity is 198 h.-p. This increased boiler capacity has been obtained not only without decreasing the efficiency of the boilers, but the efficiency of the boilers had been raised from an evaporation of 6.33 pounds of water per pound of coal to 7.75 pounds of water per pound of coal with the induced draft. This increase in boiler capacity had been obtained by an outlay of $1,500 on the five boilers, or at the rate of $300 per boiler.

If they had built a stack some 225 feet high, I do not doubt but what they would have obtained the same result, but the outlay would have been very much larger. If the boilers are kept clean it will not be forcing them to develop 1 h.-p. from 8 square feet of heating surface. I know of one boiler plant where with induced draft they get 1 h.-p. for every 4½ square feet of heating surface, and are burning the refuse from the mines.

There is another point in this connection, and that is there are a great many places where heat can be utilized with an induced draft fan, where the heat is at present going to waste. In many manufacturing plants, such as the manufacture of malleable iron, and in railroad shops where they have a large number of small and large furnaces, if these were combined into one underground duct built of fire brick, the products of combustion from these furnaces could be used for making steam to be utilized in running steam hammers or driving engines, or in heating.

Another point is the smoke nuisance. Are we going to submit to all this smoke, or is the city going to be cleaned up, and are we going to have some central boiler plants? The big boiler plants could be located down by the river front. That means the power would be developed in large condensing engines, and economizers would be used. That also means the use of induced draft. The effect of low temperature of the gases almost always brings the draft for the gases down below what was expected to be obtained. In a large boiler plant with thousands of horse power, the heat from the waste gases could be utilized, and the induced draft would be the proper method to employ. Further than that, with the induced draft in a plant located where water costs little or nothing, the gases can be freed from all solid matter and the smoke be entirely done away with.

We have already introduced the shower bath for separating the products of combustion from carbon and noxious fumes. We have made an installation of this kind in the Michigan Chemical Company's plant at Saginaw, Mich., which proved very satisfactory. The shower bath for cleansing the products of combustion in large plants in this city is sure to come. It is very simple, and where water can be pumped from the river or lake the cost will be very slight.

*Mr. Finley*—I would like to ask on about how small a boiler plant it is economical to use this mechanical draft, or is it economical to use it on any size of boiler plant?

*Mr. Still*—That is rather a hard question to answer. Take a small plant, say, 100 to 150 h.-p. horizontal tubular boiler, and there is no question but that, as far as the initial cost of the plant is concerned, a man can put up a chimney or stack for very much less money than an induced draft plant. A small engine for the fan, probably a 4x4-inch, would take upwards of 60 pounds of steam per horse-power-hour to operate it, consequently it will require from two to five per cent of the steam capacity of the boiler plant. But at any rate you can get a higher rate of combustion, you can have less grate surface, you can save in your coal, and I have no doubt in my own mind (without having gone into that question very closely) but that you can obtain so very much higher efficiency with mechanical draft than you can with a chimney, that it will pay on a plant of any size. It is seldom that an operator of a plant will put in a chimney that is much over 70 to 75 feet high on a common boiler, and with a sheet steel chimney you cannot get anything like as good draft as with the fan, and you cannot burn as cheap coal. Neither can you get anywhere near the same capacity from the boilers.

Mr. Rogers, in speaking of green firemen, made me think of a very peculiar condition of affairs that I ran across down in the mining regions of the Delaware & Lackawanna Coal Co. We have some twelve plants in there; there are four large mines and there are some very large boiler plants. I was surprised to find that they carry a depth of coal from 18 inches to 2 feet thick on the grates, and in speaking of this to the manager of the mine he said if they were to go to one of those firemen and tell him that they wanted him to fire the coal in a different way every man would walk out. So we put in two forced draft and two induced draft fans at each plant. We do not claim that there is any efficiency in the thing, but they are getting steam where they could not before, and they cannot change the conditions of the firing, even now.

*Mr. Finley*—In a boiler plant of 1,000 h.-p., without admitting for the time being that the stack will cost considerably more than the installation of a mechanical draft plant, yet the extra cost of that stack and the saving you claim for the mechanical draft, will the interest on that money pay for the maintenance and renewals of your mechanical plant? The stack will last indefinitely.

*Mr. Still*—There is no reason why one of these plants should not last indefinitely. Of course, the engine has to be kept up. One plant we have had in operation eight years, and aside from just requiring the engineer's attention, no repairs have ever been made except packing and oil.

Mr. Strong, of the American Radiator Company, had a proposition up, with their German engineer, in connection with a new plant they are building in Germany, and I spent a good many hours with him on that question. He obtained prices in Germany on a chimney and economizers, and we also made him a figure on an induced draft plant. He went into the matter very carefully as regards initial cost of the plant, interest on investment, cost of the fan and keeping it up, allowing for depreciation, etc. He figured depreciation at 15 years and the life of the chimney as indefinite. The final result of his calculations was that it represented a net saving to them of 16½ per cent to put in a mechanical draft plant, but in spite of that they could not convince the German engineer that the mechanical draft had any advantages, and they finally concluded to build a chimney, as the aforesaid engineer would have charge of the plant and less trouble in consequence would ensue.

*Prof. C. V. Kerr*—In regard to the best manner of driving these mechanical fans, in case you have a large plant, which will give the best regulation of draft depending on steam pressure, an engine or an electric motor?

*Mr. Still*—So far I have been unable to obtain from any of the manufacturers of speed regulators for motors a durable and satisfactory device that will give us the fluctuation of speed we want, with a motor for this kind of work. The continual shifting of the regulating lever causes them to blow out. We have one in New York City that is a combination of a Cutler-Hammer rheostat and a Kieley regulator, but it fuses very badly, and on that account we have kept away from the motor proposition wherever possible. We are working up a device which we hope to perfect. As soon as we have this perfected I think the motor will have certain advantages in some plants. With a motor, unless you have some outside service connection you will have to wait until you can first get up steam enough to run the generator before you can start the motor.

*Prof. C. V. Kerr*—What is the effect of the hot gases on the fan itself? Is there a tendency to corrode it?

*Mr. Still*—There is no tendency to corrode the fan or the fan housing unless you have considerable moisture, and even then the moisture will not condense until it enters the chimney.

*Prof. C. V. Kerr*—Is the friction of the air on the blades sufficient to keep them clean? Is there any tendency to polish the blades?

*Mr. Still*—Yes, you will always find they are very clean. The same way with the tubes in the boiler; you will always find the tubes clean, and they keep clean very much longer than they would by natural draft.

*Prof. C. V. Kerr*—What lubricant do you find best on the bearings?

*Mr. Still*—We use any lubricant.

*Prof. C. V. Kerr*—I am tempted to ask what the mechanical draft people were doing when the plans were being made for the great power plants in New York City?

*Mr. Still*—I think the reason for those big chimneys is merely to discharge the gases high above the ground. If they were discharged near the ground a strong wind would blow them into the surrounding buildings. If there is any other reason than this I do not know what it is.

*Mr. Rogers*—There is a plant being designed within a thousand miles from here of from 20,000 to 40,000 h.-p., where it is expected to use induced draft. It is patterned after the Manhattan power plant.

*Mr. Still*—That Manhattan power plant I believe has fourteen forced draft fans, each having a 9-foot wheel.

*Mr. Damon*—Is there a city ordinance in Chicago, regulating the height of the stack? We have a plant in St. Louis where we had to run the stack up 150 feet in order to comply with the city ordinance.

*Mr. Finley*—I cannot say. I know they have in Milwaukee, but whether they have one in Chicago or not, I do not know.

*Mr. W. E. Williams*—Just as a matter of information I would like to ask, if forced or induced draft was used on all of the boiler plants here, what the effect would be on the smoke nuisance?

*Mr. Still*—I will have to answer that the same as a friend of mine did in Syracuse, N. Y. He was before a school board, and one of the members of the board asked him how much coal it would take to run that school. He replied, "Show me the fireman." That is about the way with the coal question. Some firemen will make much more smoke than others, but if the conditions are carefully regulated and the fire is not started up all over at once, and it is a fairly well-proportioned furnace, you can reduce the smoke down to a point where you won't have such a state of things as you have around here, that is certain. The firing should be done carefully, first on one side and then on the other. Of course, it stands to reason that the higher rate of combustion you get, the less smoke you will have.

There is one plant in Detroit with a 54-inch wheel, and they have a very short stack. They put in another boiler and kept on increasing the capacity, and I have not yet noticed any smoke coming out of that chimney.

*Prof. Kerr*—Do I understand that in a chimney plant requiring, say, 24 pounds of air per pound of coal, a mechanical draft plant requires only 18 pounds of air?

*Mr. Still*—Yes, complete combustion is more dependent on draft than anything else. Another reason is, that every time you put on a heavy fire at the time you want your draft in the steam plant, that is when your steam is going down and your fires are low and you begin to fire hard to get it up again. You have to burn more coal to get that temperature up than you really need for the purpose of evaporation in the boilers. The more coal you burn, the more air you have to supply. It is a rule that has been pretty rigidly followed, and is quite accepted among designers of boiler plants, that 24 pounds of air is required for coal that runs 80 per cent carbon and 4 per cent hydrogen, and we know by experience that we can get along with 15 to 18 pounds.

*Prof. Kerr*—In which kind of plant does the mechanical draft show to best advantage, with the hand-fired or the stoker?

*Mr. Still*—With the stoker.

*Mr. B. J. Arnold*—The question of whether or not you are going to use mechanical draft or a stack depends, I think, largely on local conditions, and I believe that is what decided the New York problem. A stack must be carried up a certain height in order to be rid of the objections on the part of that city. This reason has decided the stack question, not only in the plants that have been built there, but has also decided others. The idea is to get the carbonized air high enough above the ground so that the city will not be affected by it. Otherwise I think some plants would have been built with induced draft. All, or nearly all, modern plants in New York are built with forced draft now, to be used as an emergency device. Local conditions determine the use of high stacks, and that is the condition that usually governs the stack question today, especially for railroad work and large lighting plants. That is, whether or not you will be allowed to use a short stack. If you can use a short stack, it seems to me to be advisable to use mechanical draft, and probably induced draft, if you wish to stand the cost, which is less than the cost of a stack of equivalent capacity. But if you are locating in such cities as Chicago, New York or St. Louis, some of which have ordinances requiring stacks of a certain height, you are compelled to put in high stacks.

I want to ask Mr. Still how he figures his stacks when he is compelled to put up a fairly high stack on account of local reasons, and how that stack affects his mechanical draft plant; in other words, is the high stack an assistance or an obstruction? If it is an assistance, about how much; and if it is an obstruction, about how much?

*Mr. Still*—If a chimney is high enough to produce, we will say, an air velocity of about 1,200 feet, whereas a fan at a given speed would only produce, say, 1,100 feet velocity, then the chimney would help the fan; but if the case was reversed, and the chimney produced only 1,100 feet velocity, the higher the chimney the greater is the load on the fan. That is, there is a friction that would have to be overcome.

*Mr. Arnold*—I do not know whether I see that or not. It looks to me as if there is a point where it is better to leave out the fan, and from Mr. Still's argument it seems to me there is a point where you ought to cut off that stack, and that is just the point I am trying to find, viz., how high that stack should be. I see what he means, but, with due respect to Mr. Still, I do not see whether it is so or not. Take, for instance, a stack 130 feet high and 7 feet inside diameter, to handle 1,500 h.-p. What is the solution of that with the induced draft fan? In your judgment, is that stack an obstruction or is it an assistance?

*Mr. Still*—It would be an obstruction if you found it was necessary to use a greater draft than the chimney would produce. If that chimney will give you all the draft you want, if you have a condition like that, you would have no use for the fan.

*Mr. Arnold*—The conditions were that a draft of 1½ inches must be produced.

*Mr. Still*—The chimney is an obstruction in that case, and all that length of 130 feet is so much restriction.

*Mr. Arnold*—That answers my question exactly, and that is what I wanted to know.

*Mr. Finley*—In that case, it would be better to take down the stack or cut it off from the fan, would it not?

*Mr. Still*—Yes. We had a case in Philadelphia, the Curtis Publishing Company. They increased their boiler plant until the flue they had would not do, and they could not enlarge it because they do not own the building. In that case, at certain hours of the day we had to produce a pressure in the discharge from that fan amounting to a little over 2½ inches, but the draft on the other side only amounts to about ⅝ inch, as there it is a tremendous friction that we have to overcome.

# CXLVII.

## EARLY ENGINEERING IN CHICAGO.

REMINISCENCES BY MESSRS. MOREHOUSE, L. E. COOLEY, LILJENCRANTZ, J. F. FOSTER AND SEDDON.

*April 16, 1902.*

*Mr. L. P. Morehouse*—I suppose that personal reminiscences are always the most interesting, and therefore I might say, to make it more interesting, that the first engineering work that I remember in or about Chicago was a preliminary survey which was made under the direction of the Trustees of the Sanitary District as it was organized at that time. That was in the year 1673. There were some Frenchmen going through this part of the country exploring, surveying, etc., and a gentleman by the name of Joliet was one of them. You are familiar with his name. He made a preliminary survey for a ship canal to connect the waters of Lake Michigan with the Illinois river. That was the beginning of our present drainage canal. I do not recall that the work was immediately begun. My impression is that it was not. But I know, as a matter of fact, that there must have been considerable done on that line, because very early in the history of Chicago, after our German friends began to settle here, it is a fact that many schooners crossed the bar out along that line. They are still performing that operation, I am told, and the line is very well lined with saloons. (Yes, I am speaking from personal recollection.) The work has been going on a long time, and I am credibly informed that it will be completed during the present century and that in 1973 the drainage canal and its auxiliary work will be practically completed, along with the Chicago postoffice.

The first engineering work that was really accomplished in this locality was when the United States government, in 1833, straightened out the Chicago river, which, previous to that time, had been blocked by a sand-bar at its mouth, and it turned south so that it emptied into the lake about Madison street.

In 1833 Congress made an appropriation of $25,000, and the bar was cut through and a pier built on each side and the present harbor entrance to the river was constructed. I do not at this moment recall the engineer in charge. My recollection is that when I saw the work at that time, Mr. Liljencrantz was connected with it. That kind of work—crib work, or "cribbing"—has been carried on very extensively in the City of Chicago. The Board of Aldermen for a long time was crowded with extensive operations in that line.

The next work that I recall of an engineering character was the construction of water works in 1842 by the Chicago Hydraulic Company. Previous to that time water had been furnished to the citizens from wells on their own premises, or distributed by carts. In 1842 the Chicago Hydraulic Company erected pumping works at the foot of Randolph street and carred out a pipe about 700 feet into Lake Michigan. The water was distributed through the business part and practically all the inhabited part of the city through wooden water pipes, many of which are being exhumed from time to time nowadays.

In 1848 the next memorable engineering work connected with Chicago was completed—the Illinois and Michigan canal—which was one of the great works of that time and brought to Chicago an unexampled prosperity.

In 1851 the City of Chicago took hold of the water works and began the construction of its present system. The original pumping works were at Chicago avenue, and the water was taken from a point very near the shore.

In 1863 Mr. E. S. Chesbrough, the city engineer, whose name we all revere, conceived the plan of tunneling under the lake for a considerable distance from the shore to secure a perfectly pure supply of water, and that work was begun in 1864 on St. Patrick's Day. We all know how successfully it was carried out and how that work has gone on up to the present time. When it will end none can foresee, but the city water works will remain always a lasting monument to the genius of Mr. Chesbrough. In this connection I would mention that he is the father of our present system of sewers. The system has been largely modified, of course, but the original arrangement was planned by Mr. Chesbrough, and I think work was practically begun on an extensive scale about 1856.

These, it seems to me, mark the most important of what you may call the early engineering features of Chicago. The bridges across the Chicago river have been a gradual development; everything in connection with the engineering work of the city has been a development, but these certainly were memorable events in the beginning of our engineering history. I do not know that there is anything else that I could speak of at this time. I presume there are gentlemen here who can tell us something about their own personal experiences in connection with some of the works previous to the '70s.

*Mr. Finley*—Mr. Morehouse, can you not tell us something about the early history of the Illinois Central railroad?

*Mr. Morehouse*—The Illinois Central railroad was chartered in the year 1851, and the construction of the road was begun immediately. The first portion, about fourteen miles, between Chicago and what is now known as Kensington, was constructed with special reference to allowing the Michigan Central railroad to have an entrance to Chicago. The Michigan Central railroad for a number of years had been operating a road to New Buffalo, across the lake, transferring passengers and freight to steamers, by which they were carried to Chicago. They were very anxious to get into Chicago, but money was very scarce in those days, making it very difficult to build railroads. The Michigan Central abandoned the plan of building into the city and made an arrangement with the Illinois Central for the use of its tracks from Calumet (now Kensington) into the city. That is the reason why that part of the road was the first built. The work on different parts of the line was commenced very soon, and the whole system of 706 miles was completed in the fall of 1856.

The engineering work about Chicago was a little peculiar, inasmuch as it involved the protection of the lake shore for a considerable distance from the river. To about 16th street a breakwater was built, composed of what was called crib work. I think it was twelve feet wide. The water was about nine feet deep, and the crib work rose about four feet above the water. These cribs were compartments about twelve feet square, built of twelve-inch timbers and filled with stone. Four square piles were driven in the four corners of each compartment, holding the cribs securely in place, so that the alignment of that crib work has been maintained up to the present time in very excellent condition. Subsequent cribs were built without piles being driven to secure them, and they scarcely ever retained a proper alignment. The first work was done under the direction of Colonel R. B. Mason, chief engineer of the Illinois Central railroad, who was at that time one of the foremost engineers of the country, and he always did work of the best and most substantial character. That was about the only peculiar feature in connection with the entrance of the railroad into the city.

The buildings of the company were all of stone. The passenger station at that time was the largest and finest in the country. It was 166 feet wide and 604 feet long. The passenger shed was covered with a roof of one span. All buildings were placed on piles. Colonel Mason was always very particular as to the foundations and they always stood up.

The Illinois Central railroad north of 16th street at that time was built on a pile bridge. Lake Michigan extended almost up to the east side of Michigan avenue, and, previous to the location of the road, had been making encroachments on Michigan avenue, so that at times, in storms, a portion of the roadway had been swept away. The city put in sheet piling just east of the east side of Michigan avenue. That was frail and the residents and owners of property were fearing continually that storms would sweep away the street, and the city was very glad to have the Illinois Central come in along the shore and protect the property. One of the conditions under which the road was allowed to enter the city was that it should make a continuous breakwater from the Chicago river to the city limits, then at 22d street, for the protection of the city, and that work was done at a very large cost.

The Galena & Chicago Union railroad was the first railroad built out of Chicago, and I can recall hearing one of the promoters of that road—one of its early presidents—telling about the difficulties they had in constructing the first eight miles, and the trouble they had in getting money for that purpose, taking three or four years to build a road from here to what is now known as Oak Park. There was a story told me when I first came to Chicago that at the time when they had eight miles of the road completed and were ready to operate it, the directors or the general superintendent or general manager ordered two dozen lanterns—twelve red and twelve colorless. When the lanterns arrived it was decided that the officers of the road should have the red lanterns in order that they might be known as officers. I do not vouch for the truth of that story, and as my informant was one of the officers of that road, I am inclined to disbelieve it.

*Mr. L. E. Cooley* My acquaintance does not go back quite as far as that of Mr. Morehouse. It is true that Joliet did suggest a canal across the Chicago divide in 1673, or thereabouts. It was a dream of the early French governors that dominion on this continent lay in the valleys of the St. Lawrence and Mississippi, and it is still too early to say that this dream is not prophetic.

The actual date when a positive recommendation was made in regard to a canal was in 1808, by Albert Gallatin, in a report as secretary of the treasury of the United States. Clinton is said to have visited Chicago river to promote a canal in 1826, and to have predicted a great city in forty years, of not less than 200,000 inhabitants. That was virtually realized in 1866.

We had surveys in 1820, and in 1836 the actual beginning of a canal. In 1838 General Dearborn (from whom Fort Dearborn was named) wrote to his brother, who was secretary of state of Massachusetts, that they were building a great ship canal at Chicago, which was to be not less than ten feet deep, which at that time was all the water that could be carried across the St. Clair Flats between Chicago and Buffalo. The canal was completed in 1848. I believe the first steamboat struck Chicago in 1832.

One may say that the history of Chicago, from the time it was organized, or from 1854, when it was a very small town, to 1885, is the history of one man as far as engineering is concerned—viz., Mr. E. S. Chesbrough. Mr. Morehouse has referred to the works which he started in 1856—the sewer system. He went to Europe to make a study of the systems then existing in foreign cities, and wrote a classical document on the development of the art at that time. He was opposed in the establishment of a sewer system, just as the drainage canal has been opposed, as something that the city did not need. In 1862 or 1863, when he started the water tunnel system under the lake, he was also opposed very bitterly. Mr. Chesbrough was identified with the deepening of the summit level of the Illinois and Michigan canal, which occurred in 1866-1871, by which the original design of the canal was completed so as to draw its supply of water from Lake Michigan. It was supposed that that would answer the necessities of the city for sewage disposal for a long time to come, but Mr. Chesbrough clearly foresaw that that was not the case, and he projected other works. The Fullerton avenue conduit for circulating the waters of the North Branch was undertaken in 1874 and was actually carried out. A new water tunnel under the city to the West Side was also completed. The two subways under the river at Washington and La Salle streets were also built. He had designed a conduit on 39th street for the purpose of circulating the waters of the South Fork, and this is now being carried out and may be completed in this future period about which Mr. Morehouse has spoken. Mr. Chesbrough also had in contemplation a system of intercepting sewers, and that is now being carried out on a much extended scale.

As late, however, as 1878, Mr. Chesbrough was not clear as to what the future Chicago would demand in the way of sewage disposal. The paper that he wrote at that time for the American Health Association indicates doubts in his mind. Sanitary science was not settled as to what disposition eventually would be made of sewage; whether it should be wasted as it had been from time immemorial, or whether some means of saving it for some useful purpose would be found. In this same year, in a conversation which I had with Mr. Chesbrough, outlining what had been in every man's mind from the beginning, I asked why this idea of further enlargement of the canal for the purpose of sending our sewage southward was not the ultimate solution? Mr. Chesbrough remarked that such a scheme would be an ideal solution when this city reached a million inhabitants; but, as a conservative engineer, he did not feel warranted in projecting works on the theory that Chicago would reach a million inhabitants. Mr. Chesbrough was a man of large ideas and far-seeing, but Chicago's growth has been beyond human foresight.

I was connected with the Northwestern University at that time; also associated with the *Engineering News*, which had just started in Chicago. I believe I may claim the credit of having assisted in founding that paper. With all the assurance which a newspaper man and a professor can command, I was naturally awake to new ideas and to drawing the minds of our great men. I remember talking with Mr. Chesbrough about the Chicago river, and he told me about surveys he had made previous to the fire and those that had been repeated after the fire, costing the city a great many thousand dollars, by which he had projected a dock line for a wide river, much wider than is now being carried out by the sanitary trustees, and this was nearly thirty years ago. The argument then was lack of funds, as though a city could become richer with age in proportion to the problems before it.

In 1878 I left Chicago. In 1884 I came back, and they were still carrying out works which Mr. Chesbrough had projected or conceived, although he had then for some years ceased to be city engineer.

In 1885, with Ossian Guthrie and Dr. F. W. Reilly, I drafted the report of the Citizens' Association of Chicago, which started the agitation for the present drainage canal. That report is a very good preliminary of what we are doing at this time and of what has been done. I remember stating in that report that we would have over a million inhabitants in Chicago in 1890. The full committee of the association thought it was a wild and visionary statement which the citizens of Chicago would not credit, and that it might possibly detract from the force of the report, so the statement was stricken out.

We were near the time of which Mr. Chesbrough had spoken, that when we had reached a million inhabitants the solution by means of a ship canal would be ideal. This begins our second engineering epoch with a host of new problems which the progress of the age has developed. But the recent period is not scheduled for discussion this evening.

*Mr. G. A. M. Liljencrantz*—In regard to the harbors of Chicago, strictly speaking, there are two harbors in the city; one known as Chicago harbor (in the central part of the city), the other as Calumet harbor (also located inside of the city limits). I will confine myself to the so-called Chicago harbor. I had always supposed I was older than Mr. Morehouse, but when he states that he was around here in 1673, I must change that belief. I am getting pretty old and my memory is not as good as it used to be, and that may be the reason that I fail to recollect meeting Mr. Morehouse here in 1833.

As Mr. Morehouse has stated, the first improvement of the Chicago harbor was made in 1833, according to what I have been told. Official reports of the chief of engineers were not published until much later. I have not seen any of earlier date than 1868, but from other sources I have learned that the work was commenced at the time given above, and, as Mr. Morehouse has stated, the river near the lake made a sharp bend to the southward, entering the lake, according to his statement, opposite Madison street. I had been previously told that it was near Twelfth street. A similar bend was found in the Calumet river prior to its improvement.

The first work of improvement consisted in cutting through the sand spit formed between the lake shore and this bend in the river, and the building of revetments on either side, so as to create a current by which the channel could be kept open for the light-draft vessels that passed through at that time. Over the bar outside there were only four to five feet of water.

The dock construction was commenced at the foot of Pine street, on the north side of the river, and at the foot of Michigan avenue, on the south side. From there crib-work was from time to time extended eastwardly on both sides of the river, the extent depending then, as it does now, upon the appropriations made by Congress. The north pier was thus gradually extended until in 1859, when a wide pier-head was built, whereupon was later built the first lighthouse, which was in use until in 1894, when it was removed. Eastwardly from this pier-head the City of Chicago extended the north pier for a distance of 450 feet, but in a more northerly direction, to make the entrance wider. The south pier was extended to its present limit in 1870 to 1871. East of the pier built by the city an opening was left for the formation of the so-called Ogden slip, north of the river. Beyond that gap the north pier was again extended for a distance of about 400 feet, in 1868.

In 1870 a new project was adopted, which provided for the construction of the easterly breakwater, from opposite the then existing south pier, and running southwardly for a distance of 4,000 feet. The project included also the formation of a basin by the construction, from the south end of this breakwater, of a pier toward Van Buren street, to secure an anchorage place for vessels, relieve the overcrowded condition of the river and to give protection to the wharves and slips proposed to be built between Randolph and Van Buren streets. The construction of these wharves and slips was, however, prohibited until the litigation relative to the ownership of the lake front should be concluded. As is well known, this litigation lasted for many years and the plan to build the wharves and slips was finally abandoned. In 1878 this project was modified. The southerly breakwater was proposed as a substitute for the enclosing pier opposite Van Buren street, thus making the basin larger, enclosing an area of 455 acres. This breakwater was built so as to leave an opening of 750 feet between its northerly end and the south end of the easterly breakwater. It is 3,000 feet in length, and was built in 1879 and 1880.

The same project provided for the construction of the exterior breakwater. Because of the trouble that vessels frequently experienced during northerly storms, the north pier had been extended eastwardly 600 feet in 1875, but, though this was an improvement on previous conditions, it did not prove a sufficient protection for vessels entering the harbor, for even then they frequently ran into the easterly breakwater. The exterior breakwater was therefore projected, which is located one mile north of the entrance to the harbor.

This breakwater has proved of great benefit to navigation. Vessels seldom run into the easterly breakwater now, except when "too many schooners have crossed the bar," in very bad fogs, or cases of that kind, and usually they have no trouble in entering the harbor.

In 1871 a harbor line was established, starting from where the present life-saving station is on the south pier, and running southward as far as the third wharf of the Illinois Central railroad, opposite Randolph street; thence westerly 800 feet, and from that point in a southerly direction parallel to the easterly breakwater. as far down as to opposite Van Buren street. In 1890, the southerly breakwater having been constructed prior to that time, the harbor line was extended to the southerly limit of the basin, and in 1896, it having been decided to form a lake front park landward of it, authority was granted by the secretary of war to build a bulkhead along that line. This part of the lake is being gradually filled in, and the park will probably be completed in that distant future alluded to here tonight, together with the new postoffice, the 39th street conduit, removal of tunnels, and other important improvements. The formation of the "lake front park" reduced the basin area from 455 to 270 acres.

Dredging is at present in progress in the outer basin. I might mention that the depth of the river as well as of the harbor has been gradually increased, and last year the river was dredged up to Rush street to a depth of twenty-one feet, and the basin is being dredged to the same depth for a width of about 2,000 feet, counting from the easterly breakwater westward, and down southward as far as the appropriation will permit. The specifications provide for a depth of twenty feet with an allowance of twelve inches below that depth, but it is very seldom that the contractors fail to take advantage of the allowance, so the depth will probably not be anywhere less than twenty-one feet.

It is proposed to extend this dredging eventually as far south as to the southerly limit of the basin, so that vessels can enter by either the southern entrance to it or from the river. The river being generally crowded with boats, it is intended that, when they are loaded, they shall be able to leave the docks, thus making room for other boats, and cast anchor in the basin while waiting for suitable weather to start on their journey.

Regarding pier constructions, it would hardly be desirable here to enter into details, but it might be of interest to mention that, prior to 1872, it was customary to sink the cribs directly on the sand bottom. They were usually made fifty feet in length, sometimes sixty-four feet, and twenty feet in width where the water was not over eighteen or twenty feet in depth, and thirty feet wide in deeper water. As I stated above, the cribs were sunk on the sand bottom and allowed to remain this way over winter to settle, after which the superstructure was built. It was found, however, that in practically all cases the cribs tilted and settled unevenly, and it was a very annoying and expensive work to build up to the water surface. Several plans were therefore considered to remedy this difficulty. The first experiment, in 1873, was to form a stone foundation, upon which the cribs were sunk. This proved quite an improvement. A year or two later a plan was tried of suspending the cribs on chains. Before placing one of the fifty-foot cribs, three pairs of piles were driven on either side of the site for the crib. They were sawed off at about two feet above the water level and capped with 12x12-inch timbers. Chains were attached to the bottom timbers of the cribs at the beginning of their construction. When ready to sink, the crib was placed between these piles, and the upper ends of the chains were fastened around the cap timbers, so as to give the cribs the proper height when they were filled with stone. The crib had, of course, a grillage bottom, allowing the stone to pass through. This plan proved quite successful, although it frequently happened that the chains broke, but there was no such uneven settling of the cribs as had been experienced when they sunk directly on the sand bottom. The last three cribs of the easterly breakwater were sunk by this method. In 1875 or 1876 a new device was made by which the cribs were sunk on pile foundations. Rows of piles were driven in such a way as to give support to the cribs under the side and middle walls. At the bottom of the cribs were placed three bearing timbers abreast, for each row of piles, to make sure that the cribs would rest on the piles, even if these were not driven exactly in straight lines. Thus the cribs always received good support. The piles when driven were sawed off at about fourteen and a half feet below the lake level. This plan proved exceptionally satisfactory, and a great portion of the Calumet harbor piers have been built in this manner. The southerly breakwater in Chicago harbor was also built on that plan, which has furthermore been adopted for the piers in several other harbors.

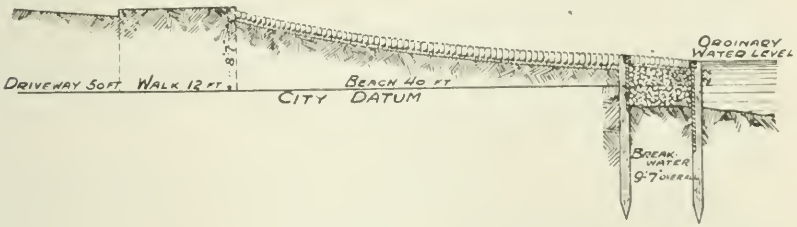
*Mr. J. F. Foster*—One hesitates to say anything tonight upon engineering questions after hearing of so much that has been done in and about Chicago by those who have long since been canonized in the engineering world.

When the park commissioners obtained possession of Jackson Park it had an area of about 600 acres. Eight or nine years later it was found that considerable inroad had been made by the lake and that the acreage was greatly reduced, so much so, indeed, that new surveys had to be made in order to ascertain the best method of adapting the original plans for the improvement to the present condition. Such surveys showed a loss of nearly one hundred acres from the original area. The first question to be determined in the improvement of the park was, what should be done to make a permanent shore line and prevent further erosion. Some engineer who had had considerable experience in the protection of the lake shore advised the commissioners to construct brush jetties. This recommendation was acted upon. These jetties were placed at intervals of about seventy-five feet along the shore, extending into the lake fifty or sixty feet. At the shore end they were connected with a wooden box sunk into the sand and filled with coarse gravel. This box was from sixteen to thirty-two feet in length, rising above the water perhaps three feet, and about five feet in width, filled with coarse gravel and planked over. The brush jetties were staked to the bottom of the lake and brush piled thereon until it was about one and one-half feet above the water; it was then loaded with heavy limestone rubble. The stakes pinning the brush to the bottom of the lake were placed at intervals of about one foot all around the margin of the brush as well as a line through the center. The stakes rose above the top of the brush sixteen or eighteen inches, and it was thought they would hold the rubble in place on top of the brush. The shore of the lake at nearly all points along the park was not more than four or five feet above the ordinary stage of the water, and there being no barrier connecting the ends of the boxes on the shore line, the water, in heavy storms, flowed around the shore end of the boxes, washed out the sand, and the jetties were in a very short time a considerable distance out in the water from the shore line. Instead of being of assistance in preventing erosion, they had really been the reverse, and within eighteen months after they were built the water of the lake had encroached upon the park another 150 feet. There were places where the then existing shore line was at least 700 feet inland from the original shore line of the park as it existed when taken possession of by the park commissioners.

The commissioners then determined to adopt some effective and permanent device for the protection of the shore. The protection of the shore line of a lake is, of course, a very simple question, though under any circumstances it is very expensive, but a desirable shore protection for a park must necessarily be different from that which would be perfectly satisfactory for other places. The most desirable shore for the enjoyment of the people would be a sand beach. Twenty years ago, with practically no experience in that line of work, I thought this might be accomplished, and a plan was prepared for a barrier along the shore line, the top of which should be at about the ordinary stage of water. It was thought that the sand back of this barrier, if brought to sufficient height so that the waves would not run over it, would not be washed out, although it might be shifted somewhat during heavy storms. The plan was adopted by the park commissioners and the construction of the shore protection was entered upon. The barrier consisted of two lines of piles driven longitudinally along the front of the park from 100 to 200 feet out in the lake. The lines of piles were about eight feet apart, and the piles in the lines were six feet apart. Between the piles in the rows four-by-four oak stakes were driven about four feet into the sand bottom of the lake, held in place by girts and wales to the piles. The space between the two rows of piles and stakes was then filled with cedar bark and covered with a paving of limestone blocks averaging twelve inches in depth. After this barrier was constructed a dam of cedar bark was placed along the bank to prevent water flowing over into the park during storms, and the lake shore was left in that condition for a period of about one year. It was found that during that year there had been some deposit behind the barrier. Another hopeful year was permitted to pass, when it was found that there had been very much more sand washed out than had been deposited the year before., Then it was thought that possibly if a beach was formed upon a slope usually formed along the sand by the action of the waves, starting back of the barrier and rising to a height over which the waves would not run, covered with clay six inches in thickness, well filled with large pebbles rammed into it, it should maintain its position. But it did not. Stone block paving was then resorted to, and the

LAKE SHORE PROTECTION

SECTION of FINISHED BEACH



beach was paved from the back edge of the barrier for a width of fifty feet, rising to a height of about ten feet above city datum at the back or upper edge. The blocks in this pavement are twelve inches in depth at the front or back edge of the barrier and six inches in depth at the land or upper edge. The blocks were laid in two inches of gravel and the joints between the blocks were filled with gravel, which soon became impervious to water. The shore along the entire length of Jackson Park has been paved in this manner, except where walls are required for the protection of buildings, driveways, concourses, etc.

This method of shore protection has proven very satisfactory, and while not as agreeable for children to play upon as a sand beach would be, it is, on the whole, about as satisfactory as anything that has so far been suggested. There are many places on the beach where sand accumulates at times, making very pleasant places for children to play. This work in Jackson Park was the first of this character of shore protection that was made on the lakes, so far as I know.

The water level in the lake, as you know, has been dropping for the last ten years, so that now the top of the barrier, which originally was at the level of the lake, is most of the time from eighteen to twenty-four inches above it, which, of course, is undesirable and may make it necessary to drive another row of piles further into the lake, carrying the paving further outward to a lower level. Since the completion of this work in 1891 there has been no erosion or any breaks in the beach paving of any consequence, although here and there the paving in the barrier and sometimes in the beach will settle a little, but it is then given immediate attention, and, on the whole, the cost of keeping the beach protection in good condition does not exceed what would be necessary in the maintaining of a driveway of the same length and width. A cross-section of the character of this shore protection has been handed to the secretary, should any of you be sufficiently interested to look more closely into the details of construction.

*Mr. Jas. A. Seddon*—With about two years residence in this city, I think our President must have meant to be funny when he called on me for "Reminiscences of Early Engineering Works in Chicago." But time has no beginning and no end, and past and future are but questions of the point from which you take them. To meet the challenge, then, I will simply shift this point to fifty years ahead, and speak of the "Early Engineering Works in Chicago" from the standpoint in the middle of the century.

I would first note, what perhaps is of most interest to those present, the way the city got its subway. The matter was discussed in the early part of the century. The city engineer had one plan and other engineers different plans, but the telephone companies, gas companies, electric light companies, water pipes and sewer mains went right ahead and used up all the space underground, so that when the public decided to do something there was no space left underground to do it in. This was a difficulty until an engineer of that day suggested that, as they could not make a subway below the ground, it would be just as well to put the sidewalks of the city up about fifteen feet higher and have a subway already excavated, with the ground floors of the tall buildings as basements.

As the municipal street car service of that day had a time card of about an hour from 39th street to Adams street, it was very desirable to have the air spaces between the raised sidewalks to sell to a new traction company that would really fill some of the requirements of rapid transit. This, when sold, brought so large a sum that those who worked it through the council actually could not get all of it, and the city then found itself in possession of a large sum to spend on improvements.

The first thing to improve at that time was the Chicago river, which had been so improved by the Sanitary District that its condition was intolerable. An expert commission was appointed to consider this problem, and a venerable member of that commission organized a search into the old files of the district. This unearthed a report of L. E. Cooley's of 1901, which covered the ground very thoroughly, and the commission made quite a reputation by recommending it. The work was carried out substantially on the project outlined by Mr. Cooley a quarter of a century earlier.

Following this, it began to be apparent to the government that an eight-foot waterway in the Illinois river was hardly suitable to connect with the twenty-four-foot waterway across the Chicago divide. At that time, also, the position of congressman was so much less profitable than that of alderman that it was not difficult to get really intelligent men to send to Washington, and the interests of Chicago in a waterway to the gulf began to be considered. The improvement of the Illinois river was developed just as it had been outlined in the ancient history of 1885.

The lake-to-the-gulf waterway had quite an interesting history. The thousand miles from Cairo to New Orleans had been improved so greatly, at an expense of some eighty million dollars, that the depth was about three or four feet less than when the work was first started. There had been built an earth embankment along the river, shutting off the floods from the bottom lands, and the high water flow line had risen until it was about up to the eaves of the houses of the people behind the levees.

In that chapter of accidents which make the great floods of a river, the spring rains and melting snows came down the frozen slopes of the Allegheny, just as heavy rains in the northwest brought the Missouri and Arkansas in flood to join the Ohio, while warm weather in the lake district sent down the spring floods from the upper Mississippi and Illinois rivers. The earth embankments of the lower Mississippi went down before this combination, and the flood waters swept over a thickly settled and highly cultivated district forty to sixty miles wide and 500 miles long, from Cairo to the gulf.

This was the end of the plans of the Mississippi river commission and a more rational project for improving the river and protecting the valley was adopted. In this a deep waterway was easily secured and finally joined to the improvement of the above from Chicago to the Mississippi.

It is only recently that I went down the line in an ocean steamer and saw this dream of the centuries realized. But the weight of years was upon me and I was alone with the memories of its beginnings; perhaps it was malaria; but I summed up the history as fellows: A great work is a great misfortune to the engineer who has the bad luck to first conceive it. It drives him to a life of effort without reward; dooms him to continued disappointments, and promises him that he will never live to see it accomplished.

## CXLVIII.

# THE ECONOMIC NEED OF TECHNICAL EDUCATION.

By Victor C. Alderson, Dean of Armour Institute of Technology, Chicago.

The day of the untrained man is past; the day of the technically trained man is here. At no time have the untrained, the unfit, the poorly prepared been so ruthlessly weeded out of the professions, the arts, the trades and business callings as they are to-day. The incessant demand, heard by him who has "his ear on the ground," is for young men in the vigor of manhood, whose eyes, ears and hands, as well as minds, are trained to do the work demanded in modern industrial pursuits. Those who stand midway between the active industrial workers on the one hand and the oncoming groups of young men on the other, like the administrative officers and professors of our technical schools, are able to take a broader and more comprehensive view of the field of supply and demand than most others.

The pedagogical reason for the existence of manual training in a school curriculum is identical with the reason for the existence of drawing, singing, number work, science work or reading—no more and no less. To be perfectly fair and impartial, then, it must be admitted that the term "Manual Training School" is as erroneous as "Mathematical Training School," "Science Training School" or "English Training School." The names primary, grammar and high school are quite sufficient, for in each school mathematics, English, science and manual training should enter as co-ordinate subjects. Manual training should no more give name to a secondary school than philosophy should be the describing feature of a university. Rather should shop work, science and hand manipulation be an integral part of the curriculum of all grades of school work, from the kindergarten up. The simple hand work of the kindergarten, the science work of the primary school, sewing and cookery for girls and carpentry for boys in the grammar grades, are all movements in this direction. The manual training of the future, and the very near future, will be hand work of some kind adapted to the ability of the student, whatever may be his stage of advancement. Manual training will then lose the distinctive feature it now holds as an adjunct to a high school course, and become one means of education applicable to all grades of instruction.

Most, if not all, recent improvements in educational methods in this country have been purely academic or philosophic; they have been evolved by musing in the library, or perhaps from class-room experience; but none of them have resulted from a close acquaintance with the real conditions of the industrial and business warfare into which the student enters when he leaves the school. The so-called "systematical development" given to young people is but a twentieth-century way of training a "jack-of-all-trades." The one thing needful will not come from teachers' conferences, nor county institutes, nor the august meetings of school superintendents, for the attendants at these assemblages have not, and cannot get from their experience, the proper point of view. The great majority of the public-school teachers are women whose environment has been limited by the home, the school and some social functions. The number of men engaged in teaching who have done serious practical work outside of the school-room is small. The academic circle which they tread reminds one of the Illinois farmer whose circle of experience was to raise more corn to feed more hogs, to buy more land—to raise more corn to feed more hogs, to buy more land—*ad infinitum.* Educators of to-day should break out of the circle in which they are traveling and look at matters from a new point of view. This should be from the vantage ground of the factory, the workshop, the railroad or the counting-room; it should be industrial and commercial rather than academic. The practical needs of everyday workers should be considered, after a scientific study of conditions at present existing. There should be no prejudgment by the social or educational philosopher who knows not the difference between a " shaper " and a " milling machine," and evolves theories of what ought to be, but never is. Industrial life in its relation to national growth and prosperity, in its influence on international competition, and in its demands upon educators, offers interesting fields of investigation. This change of view from the speculative and philosophic to the practical and industrial will result in many desirable changes for the betterment of our system of education. Hitherto the speculative element has been supreme; the time has come for this influence to be tempered by the introduction of more rational and scientific views.

With advancing civilization, with the luxuries of yesterday becoming conveniences to-day and necessities to-morrow, with our products going to far-away lands in competition with local goods, with competition becoming sharper day by day, with the margin of profit becoming steadily narrower, it is found necessary to seek new lines of economy. In the accurate application of the laws of science, an almost limitless field is open. Mere practice, no matter how long continued, cannot long avail against theory followed by intelligent application. A stupid fireman can burn up the profits of his establishment by ignorant firing; an engine man was recently discovered running an engine for no other purpose than to get exhaust steam to heat his building. He was a "practical man of long experience." A soap manufacturer who had depended upon the "knack" of one workman for many years nearly went into bankruptcy when the man died, for no one else seemed to have the requisite "knack"; but the employment of a trained chemist without the "knack" regained for him his lost business. A large railroad company recently saved more than half a million dollars in six months by equipping a laboratory in connection with its machine shops and putting in charge a technically trained man—one who could unite theory with common sense. Day by day the demands for scientific and technical training become more and more emphatic. The present age has truly been called the age of science, but with this designation the story is only half told. Pure science to be of the greatest value must be applied. The application of science to industry has made this the age of technical education; it has changed many of the conditions of life and has given rise to new problems, the solution of which depends in a high degree upon men who have received a technical education.

Technical training, in its broadest significance, should be made to include professional schools, as of law, medicine, theology, engineering, dentistry, pharmacy, the special research work of universities, as well as the more modest schools for the textile industries, the mechanic arts or domestic science. Although professional training may, in this broad sense, be termed technical, yet for the present purpose it will be best to limit its significance and apply it only to the arts and crafts. A dozen years ago the introduction of manual training was always preceded by a spirited controversy; to-day its value is generally conceded and its introduction is becoming fairly common. Not only is it incorporated into the high school curriculum, but it is fast going where it especially belongs—into the graded schools, as an organic part of educational training. In another dozen years the necessity for advocating manual training will probably have ceased. What new features will be advanced to take its place? What new element in educational progress will be demanding recognition? In all probability it will be secondary technical education. Leaving out of consideration the two extremes—unskilled labor at the foot of the educational ladder and those professions at the top which demand a preliminary college training—there are many vocations in the middle ground for which a technical training is necessary. This broad field has been cultivated very little in this country. England, France, Holland, Belgium, Germany, Austria and Switzerland have all done more than we have, and it may not come amiss to examine the system of technical education in one of these countries.

Switzerland is best known to Americans as a region of mountain scenery, but it is an object-lesson for us in a manner not yet fully recognized. The natural conditions under which the Swiss people have struggled for the past six hundred years have been so burdensome and their industrial success so pronounced, that Switzerland is to-day the best of the European countries in which to study the close relation which exists between the technical education of the masses of the people and national industrial prosperity. There are fewer people in all Switzerland than in Greater New York; the largest city—Zurich—contains only 150,000 persons; the area of the country equals the combined area of but three of our smallest states—Massachusetts, Connecticut and Rhode Island; of this area 29 per cent. is utterly unproductive even for the frugal Swiss; 21 per cent. is forest; 25 per cent. is meadow and grazing land; 13 per cent. under fruit; 12 per cent. is under crops and gardens; the country has no seaport, no navigable river, and no lake of commercial size; she has little or no natural wealth; she must import her raw materials, work them up into salable form and export them; lines of transportation are expensive and rates high; the amount of fertile soil is meager, and would scarcely make a respectable-sized Western ranch. In the United States we have been allowed to blunder at will, to be improvident and wasteful; we cut down our forest with reckless disregard for the future. Twenty-six years ago Switzerland enacted a law that her forest area should never be reduced; and since that time for every tree that has been cut down another has been planted. Forced by almost cruel natural limitations to rigid economy, both of material and labor, required to solve the problem of industrial success under exacting requirements, Switzerland has given us a solution which it behooves us to examine with considerable care. That solution is the careful, systematic education of each citizen—be his station in life high or low—so that his efforts will be efficient enough to meet competition in similar lines of work the world over.

Like the United States, Switzerland has no national school system. The constitution of the federation allows the Federal Government to establish a polytechnicum, a federal university and other institutions of higher instruction or to subsidize such local schools as may be selected. Provision for elementary instruction must be made by the several cantons, but the Federal Government in most cases subsidizes these cantonal schools. There is no Federal university, but six cantonal universities exist at Basel (founded in 1460), Zurich (1835), Berne (1834), Geneva (1873), Fribourg (1889), and Lausanne (1891). The polytechnicum at Zurich (founded in 1854) is supported entirely by the Federal Government. The school covers the higher scientific and technical fields in a most thorough manner. For accuracy of instruction, completeness of equipment, and high professional standard, it is the peer of any technical school in

Europe. It has the proud distinction of having more of its graduates holding positions of responsibility, and of attracting more foreign students, than any other Continental technical school. With a most complete cement-testing laboratory; a mechanical laboratory covering every possible demand that can be made upon it; with a department of electricity equipped regardless of expense; with extensive departments of chemistry, forestry and agriculture; with a new department devoted to the testing of building material alone, it is evident that the Federal Government has provided liberally for the most advanced instruction in technical lines. There seems to be no fear in the minds of the Swiss that a man can be too scientific, or that too deep a study of the scientific basis of industrial questions is possible.

Next below the Zurich Polytechnicum are three technica, or technical schools, offering less theory and more practice, and relating their work more closely to the trades and industries. One is located at Bienne; the second, at Winterthur, is noted all over Europe for the thoroughness of its instruction and the success of its graduates; the third is at Burgdorf, where Pestalozzi taught his first school and where Frœbel at one time was developing his philosophy of education. This group of technical schools gives scientific character to the entire Swiss system of technical education.

The trade and industrial schools—to be carefully distinguished from the group first described—have been established to teach the homely trades, and are a conspicuous feature in the educational and industrial life of Switzerland. They are found in every canton, and are intended to make the local industries more successful. Some cantons with a population not over 300,000 have as many as a hundred of these schools, enrolling more than 3,000 students.

The watchmaking schools have had a long existence, the Geneva school beginning as early as 1770 with the desire of a journeyman watchmaker, Louis Fargare, to learn more of his trade than the ordinary school instruction provided. Besides the school of watchmaking at Geneva, which has a world-wide reputation, and has contributed largely to the success of the Swiss watches, other schools exist at Locle, La Chaux de Fonds, Neuchatel, Fleurier, Solothurn, Bienne, Porrentruy and St. Imier. In these schools the course covers from three to five years; the age limit is thirteen or fourteen years; vacations are few and brief. At Locle the school is open every day in the year except Sundays and holidays. At Neuchatel three weeks vacation is allowed in summer. The tuition is invariably higher for foreigners than for natives. At Fleurier the charge is $1.93 per month for natives and $4.83 per month for foreigners. The pupil on entering one of these schools enters into a contract of apprenticeship with the school authorities. At St. Imier a contract must be signed by the parents or guardian. At Porrentruy the pupils are on probation for the first three months, and may be dismissed if found unfitted for the work. At Solothurn pupils must pass a theoretical examination and afterwards a practical test before entering fully upon their apprenticeship. If they leave before the expiration of their contract, a fine of not more than $1.93 per month may be exacted for the unexpired term. The amount of practical work is greatly in excess of the theoretical. At La Chaux de Fonds theoretical instruction is given for only ten hours per week in the first year, twelve hours per week in each of the second and third years, eight hours per week in the fourth, and only seven in the fifth year. All the rest of the time is given to practical work. The object of these schools is primarily to give instruction in every detail of the art of watchmaking. How well they have succeeded all the world knows; but it is not so well known that these schools have converted regions naturally fit for nothing but growing pine trees into important industrial centers.

In 1888 a school of metal-working was established at Winterthur, as a part of the Industrial Museum, under Federal control. The object was to educate skilled workmen for the various branches of fine metal-work. Attendance is in the form of apprenticeship; the course three years in length, and the age limit fifteen years. At Brienz, the present center of the wood-carving industry, a school of wood-carving was organized in 1883, under municipal control. Tuition is gratuitous, but a contract of apprenticeship is required. This school has a fully organized faculty; instruction covers not only the art of wood-carving, but the distinctive characteristics of the different woods and the manufacture of all needed tools. Not only are the usual styles of carving studied, but special attention is given to the plants and animals peculiar to the Alpine region, as every tourist in that country knows. No better illustration of the value of technical education can be found than in the straw-plaiting schools like that at Wattwyl. These had a very humble origin, and were established to teach the people in the poorer regions of the sub-Alpine districts a useful occupation. The result has been to create a new industry and to convert regions naturally poor into flourishing industrial centers. There are also shoemakers' schools, with a peripatetic staff of instructors who give short courses wherever classes can be formed. They also issue publications to the trade, dealing with subjects of technical interest, as the structure of the human foot, or the reasons of the military authorities for the specifications relating to the contracts for boots and shoes for the army. Somewhat different in plan is the school of silk-weaving at Wipkingen, near Zurich, which is owned by the Association of Silk Manufacturers of Zurich. Only a few of the graduates of this school are ordinary weavers; most of them hold superior positions, as proprietors, superintendents or master weavers. The School for Carpenters and Shoemakers founded at Berne in 1888 by municipal authority, but aided by Cantonal and Federal grants, is peculiarly interesting. Instruction is gratuitous; hours of instruction are from 7 a. m. to 6 p. m., with a free dinner at noon. The object of the school as published is distinctly utilitarian; viz., to teach thoroughly a trade, to investigate the latest improvements in the trade, and to meet the increasing competition of foreign labor by putting domestic labor on a high plane of efficiency.

The needs of women are by no means neglected. A private school of ladies' tailoring and needlework, with a three-years' course, at Zurich; a trade school at Berne, teaching plain sewing, ladies' tailoring, embroidery, ironing, cookery, housekeeping, mending and making children's garments; a housekeeping school at Worb, which is self-supporting, and has more applications than vacancies; a housekeeping school at Buchs, with a three-months' course. popular with young ladies about to be married; a trade school at Basel, which has enrolled nearly three thousand pupils since its organization in 1879; a school of art and needlework at Zurich, with a curriculum of such artistic, educational and scientific merit as to make it a model for other schools; schools at Berne and Lenzburg to supply the demand for trained and competent household servants. All these emphasize the necessity for giving women as well as men a technical training.

Industrial art schools exist at Geneva and Zurich. The one at Geneva is the oldest in Switzerland, founded in 1751, and is attended chiefly by persons already employed, but wish to devote their spare time to improving themselves in the artistic side of their work. At St. Gallen, the center of the lace industry, a special school devotes its attention to embroidery and designing. In Zurich alone there are seven schools for woodwork; in Fribourg schools for bookbinding, basket-braiding and stonecutting; in Bienne, a school for railroading; at Waedenschwyl, a school for fruit growers and gardeners; at Zurich, Berne and Neuenburg, schools for theoretical and practical agriculture; at Geneva, a school for horticulture; at Sursee, Brugg and Lausanne, winter agricultural schools; at Ruti, Fribourg and Lausanne, dairy and cheese making schools; at Geneva, Neuenburg, La Chaux de Fonds, Berne and Winterthur, commercial schools. In addition to the already extensive list must be added a large number of institutions designed for the instruction of the humblest members of the working classes. The first of these—a drawing school for apprentices—is now nearly a hundred years old. Between 1820 and 1830 three others were established at Aarau, Baden and Zug; between 1840 and 1850 nine were organized, and between 1850 and 1865 seventy-eight more. Since that time their number has increased with great rapidity, and now reaches into the thousands, while the attendance reaches tens of thousands. Sessions are held evenings and Sundays. The original idea of teaching drawing has been maintained in many, but in others distinct industrial courses in cabinet-making, tailoring, upholstering and other trades have been introduced.

Swiss education is the result of no single philosophy, no one method, no selfish utilitarian object; it has not been dominated by social reformers nor by mere theorists; it is a composite type, the result of many conflicting views and necessities. Throughout the entire system can be seen, however, an attempt to solve the problem of the relation between education and industrial prosperity. This point of view is the one thing needful in developing our own system of technical education, and the one idea which we can best borrow from the Swiss. With them no valuable feature—either cultural or technical—is ignored. Each branch of knowledge is prized according to its value as discipline or as a distinct aid in professional or industrial pursuits. Their object is not only to train men and women for their vocations, but to build up new industries or at least to extend and strengthen those already established. They have even enriched the humblest callings with many applications of art, skill or science; they have expended money liberally upon every form of technical education which would increase the workingman's efficiency; they have transformed regions naturally poor and barren into thriving communities; they have entered freely into international competition, and have made the world their market-place; they have shown that technical education is an economic necessity, worth many times its cost. The commercial and industrial success of Switzerland, achieved in the face of great natural obstacles, shows conclusively that the surest foundation for industrial properity lies in a complete and thorough-going system of technical education.

Technical education in this country is a product of the last quarter of a century. Before 1875 only a few schools pretended to give a technical education. The first legislation which gave a decided impetus to this form of education for the American youth was the Morrill Land Grant Act of 1862. This act granted public land to the several states, apportioning 30,000 acres for each Senator and Representative, to be devoted solely to the advancement of instruction in the agricultural and mechanic arts. The full effect of this act was not felt until after the beginning of the last quarter of the century, when there was established in almost every state a school to carry out the purpose of the act. From that time on the growt of technological education was remarkable, whether we consider the actual outlay upon material equipment, the increased number of students, the constantly improved methods of instruction, or the continued elevation of the standard of instruction. In addition to the governmental aid rendered, many private citizens subscribed liberally to the needs of institutions already established, or made large endowments for new ones. This great advance came from a general acceptance of the view that industry needed the aid and assistance which comes from technical training. With this change of industrial demands came the needed supply in the form of young men trained, not in the classic halls of some favored university, but in the workshops and the laboratories of institutes of technology. These men are educated to understand the fundamental principles of science not merely in their broad, general aspect, but in every matter of practice, detail and application. They supply, to only a limited extent, however, the needs of modern industry, since they furnish merely the highest grade of workers, as does the Zurich Polytechnicum and the technica at Winterthur, Bienne and Burgdorf. They furnish a technical training not for the many but only for the few. What should be done for the great army of workers in our industries, who need at once the skill of the mechanic, together with sufficient intelligence and training to understand the directions of the professional engineers above them? Their number is legion. At the present time this country makes little or no adequate provision for their instruction. This is the realm of secondary education. Whenever we, as a nation, secure the proper point of view—unhampered by the ultra conservatism of the simon-pure schoolman—and approach the subject as the Swiss have done, from a practical, common-sense, industrial standpoint, and build our industries on the solid foundation of science, as exemplified in technical education, then our industrial supremacy will be assured.

The most ringing note on this subject in recent years was sounded by the Advisory Committee invited by the trustees of the Carnegie gift to present a plan for the technical school which Mr. Andrew Carnegie proposed to establish in Pittsburg. After considering all phases of the question this committee recommended the organization of three schools to be called respectively the Carnegie Technical College, the Carnegie Technical High School, and the Carnegie Day and Evening Classes for Artisans. The second of these schools was to be most radical. The Carnegie Technical High School as outlined would extend the scope of the present high school to include, besides the subjects ordinarily taught, engineerin principles, steam engine and central station practice, pattern makin machine-tool work, blacksmithing, steam fitting, surveying, machine design, instrument-making, founding, photography, glass-blowing, and such other subjects as the local industries might demand. The establishment of such a school would be the Americanization of the foreign trade and industrial school; if it were copied and made general, it would solve for us the question of secondary technical education.

In considering so radical a measure some important features should be emphasized in order to avoid misapprehension. The main idea in such a plan would be to take a boy just graduating from the grammar school and give him a good secondary education, together with a training on one or more technical or trade lines. Such a scheme would be unsuccessful if the school were to be maintained on the usual high school lines of to-day; it would necessitate a highly elastic or elective plan of operation, because no individual could successfully study all the subjects offered. The routine courses in physics, chemistry, mathematics and drawing would necessarily be much shortened; but every progressive teacher knows that much of these subjects, as at present taught, is of little value in strictly technical pursuits. Each one can be revised and reduced to advantage. Much of the laboratory, drafting-room and testing work now done by the technical colleges could be incorporated into the courses, and we should have technical high schools as real "people's colleges." There can be no reasonable doubt that our technical education in the United States is weakest in this spot. In our high-grade institutes of technology we are training the commissioned officers of our industrial army, but the great mass of non-commissioned officers and privates are left uncared for. As indicated in the report of the Carnegie committee, technical education may be said to run parallel with the general lines of education, and be divided into three parts, corresponding to the grammar, high school and college grades of the established system. The lowest grade is generally picked up in the shop by boys without special training, who have had merely a grammar school education. It is represented in Switzerland by the Sunday, holiday and evening schools for artisans. It develops the "practical man." The highest grade is represented by the polytechnicum and technica in Switzerland and by technical colleges and institutes of technology in this country. These represent the phase of technical education that demands thorough knowledge of mathematics and the sciences, and is distinctly professional in character. Between these two extremes lies the region of secondary technical education which is represented in Switzerland by the trade school and the specialized technical school. In the United States it is represented by more or less feeble efforts in a few trade schools, in a limited number of private institutions aimed to help the workingmen, and in night schools. Besides these instrumentalities there is another, arisen only within the past few years, which for pure bigness eclipses all other efforts—the schools of correspondence. While our educators have been discussing mere theories and methods and have been building a Chinese wall about their so-called superb school systems, shutting out all who were too large to walk through the narrow gateways which they themselves had made, private enterprise has discovered that half a million young Americans outside the walls were hungry for a technical education. Since they were forbidden to enter the sacred city, technical education was sent out to them. When the history of education shall have been written, no greater reproach will rest upon the educators of this decade than their failure to hear the call of this multitude for an education suited to their needs. Technical education is one of the greatest needs of an enlightened democracy and should not be left to private enterprise. With state normal schools where young men and women can be trained for teaching, with state universities furnishing instruction in agriculture, dairying and stock-raising, besides training engineers and librarians—technical education supplied at state or national expense—it is evident that we are irretrievably committed to the policy of providing technical education at public expense. If the farmer's son can secure at the state university free instruction in scientific agriculture, what good reason is there for depriving the son of a mechanic from securing free instruction in engineering practice, machine tool work, or any other industrial calling, at the city technical high school? The answer of the schoolmaster that the public schools are intended not to teach trades but to develop character, citizenship and general culture, is totally unsatisfactory. We must remember that in order to become a good citizen a man must first secure a livelihood by honest toil; that whatever conduces to greater industrial efficiency in the individual increases the national prosperity and indirectly improves citizenship. Technical education does this. Furthermore, if it is proper to train civil engineers, stock-raisers, butter and cheese makers, librarians, and the teachers themselves at public expense, why should machinists, enginemen, carpenters, plumbers and house painters be excluded? No cleavage line can be drawn. If technical education is a good thing for one class it is equally good for others. Hitherto the ranks of such workers have been supplied by the influx of foreigners trained abroad, aided to some slight extent by apprentices from selected industries. But we should not, as a nation, depend upon any such uncertain supply. We should follow the example of Switzerland and, recognizing the dependence of national prosperity upon technical education, set about the task of providing an education for all classes of workers suited to their lives. The technical high school, if properly equipped and put in close relationship with the trades and industries, will satisfy this national need; it will not be a copy of the European trade school, but rather an adaptation of the trade school which will be in harmony with American thought and American educational ideals.

Industrial warfare is not a new idea, but its sociological effect in giving impetus to technical education during recent years is noteworthy. We are familiar with martial warfare. Our newspapers for the past few years have been teeming with reports of battles, of warfare, of disease and death as the concomitants of war; we have been called upon to pay homage to the prowess which has conquered our enemies on land and sea; we are playing the part of hero-worshippers as we have not done since the Civil War. But in the midst of all this clamor there has been going on—largely unknown and unnoticed—the most bitter, the most relentless war in the history of the world; a war not for territory, not for naval nor military glory, but for wealth, for industrial supremacy—a contest of brain with brain, skill with skill, economy with economy, technical training with technical training. It is only another example of the "struggle for existence." The war in South Africa or the Philippines is less fatal to the workingman than the ceaseless competition of similar workingmen in other countries. It is this unremitting rivalry between workers of the same class the world over that makes the cultivation of the workingman's powers by means of technical education an absolute necessity. That nation that neglects to equip its workmen with the armament of industry—technical education—will surely be defeated and become a decaying nation. These workers should receive immediate and thoughtful attention, for they are the bone and sinew of successful national and industrial life. That they should be technically trained through the medium of the technical high school is at the present time the greatest economic need of the American people.

## ABSTRACT OF THE MINUTES OF THE SOCIETY.

### SPECIAL MEETING, MARCH 22, 1902.

A special meeting (No. 468) of the Western Society of Engineers was held on Saturday evening, March 22, in the rooms of the Society. This was a "Smoker" at the invitation of the Entertainment Committee, who took charge of the meeting through its Chairman, Mr W. J. Karner. About fifty members and guests were present. Entertainment was furnished by some colored musicians, and refreshments were served.

Mr. Karner laid before the company the idea of having a "Ladies' Night" some time after Easter, which would probably consist of a musicale and reception, followed by dancing. There was no special discussion of this matter, and it was simply presented to the members of the Society that they might consider what they desired to have the Entertainment Committee do.

The meeting adjourned about 10:30 p. m.

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### *REGULAR MEETING—April 2, 1902.*

A regular meeting (No. 469) of the Western Society of Engineers was held in the Society rooms April 2, 1902. The meeting was called to order at about 8:15 p.m., with President Finley in the chair and about sixty-five members and guests present.

The minutes of the regular meeting held March 5, and also of the special meetings held March 19 and March 22, were read and approved.

The following list of newly-elected members was announced:

| | Grade. |
|---|---|
| W. W Gaffin, Sioux City, Iowa | Active. |
| Chas. J. Poetsch, Milwaukee, Wis. | '' |
| Burton W. Perrigo, Milwaukee, Wis. | '' |
| Robt. Kunstman, 84 Adams street, Chicago | '' |
| W. T. Curtis, Wilmette, Ill. | '' |
| Jas. H. Dunbar, La Salle, Ill | '' |
| Euclid P. Worden, Milwaukee, Wis. | '' |
| Wm. T. Reeves, Chicago | '' |
| Harrison S. Bowen, Chicago | '' |
| Gwavas F. Beckerleg, Chicago, from Junior to | '' |
| Frank E. Hermanns, Chicago | Junior. |
| Myron W. Priseler, Chicago | '' |
| Jas. C. Hain, Chicago. | Active. |
| Chas. Dunham, Chicago | Associate. |

Also the following list of new applications was read:

| | |
|---|---|
| Leonard B. Mason, 634 Washington Boulevard, Chicago | Junior. |
| Samuel B. Harding, Waukesha, Wis. | Active. |
| John Y. Bayliss, Guayaquil, Ecuador | '' |
| Edward J. Fucik, Chicago | Junior. |
| Joseph Wright, Princeton, Ill. | Active. |
| H. C. Holthoff, Milwaukee, Wis | '' |
| Louis Elliott, 1110 Monadnock Block, Chicago | Junior. |
| Chas. W. Rogers, Chicago. | Active. |
| John C. Sample, Chicago | '' |

Mr. S S. Greeley introduced a set of resolutions, setting forth the importance that the County of Cook and the City of Chicago should possess proper mural or bench standards of length, officially adopted by their respective legislative bodies, with which engineers, architects, contractors, surveyors and others may compare their instruments of measurement.

The Chairman requested an informal discussion of the matter, and Mr. Seddon moved that the matter be favorably considered, and that the President appoint a committee of five (5) to look into this subject and make a report. Motion carried.

On motion of Mr. Warren R. Roberts, a vote of thanks of the Society was extended to Mr. Greeley for the very valuable service he had rendered in bringing the matter before the Society in such an excellent manner.

Mr. H. W. Parkhurst was then introduced, who presented his paper on "Wet, Dry, or Medium Concrete." This paper had been printed and sent out in advance, but was reviewed by the author. Discussion followed from Messrs. Seddon, L. E. Cooley, Finley, Tratman, Reichmann, Condron, Roemheld, Bremner, Trumbull, Schaub, Sherman, Siefert and W. R. Roberts.

Meeting then adjourned about 10 p m.

### *SPECIAL MEETING—April 16, 1902.*

A special meeting (No. 470) of the Western Society of Engineers was held on the evening of April 16, in the Society's rooms, President Finley in the chair, with about sixty-five (65) members and guests present.

The subject was "Early Engineering in Chicago." Mr. L. P. Morehouse opened the reminiscences, and was followed by Messrs. L. E. Cooley, Liljencrantz, J. F. Foster and Seddon.

The meeting adjourned about 10 p.m.

### *SPECIAL MEETING—April 25, 1902.*

A special meeting (No. 471) of the Western Society of Engineers was called for Friday evening, April 25, at the invitation of the Local Honorary Secretary Mr. R. H. Pierce, of the American Institute of Electrical Engineers, to be present at a meeting of the local members of that society.

The papers presented that evening were electrical in character, as follows:

"Power Consumption of Elevators Operated by Alternating and Direct Current Motors," by George F. Sever, of New York.

"Telpherage," by Chas. M Clarke, of New York.

The evening was fully occupied by the first paper and the discussion of the same from Prof. Woodworth of Lewis Institute, Messrs. R. H. Pierce, Lyman, Lofts, Mabbs, W. J. Warder, Ayres, Hobart, Cutler, Clarke and L. A. Nichols.

The paper on Telpherage was read by title only, because of the lack of time.

There were about fifty present.

The meeting adjourned about 10:45 p.m.

### *REGULAR MEETING—May 7, 1902.*

A regular meeting (No. 472) of the Western Society of Engineers was held in the Society rooms on the evening of May 7, 1902, with Past-President L E. Cooley in the chair and seventy-eight members and guests present.

The minutes of the regular meeting of April 2 and of the special meetings of April 16 and 25 were read by the Secretary and approved.

A report for the Board of Direction was presented by the Secretary relating to new members in the Society. The following new members have been elected:

| | Grade. |
|---|---|
| Leonard B. Mason, Chicago | Junior. |
| Samuel B. Harding, Waukesha, Wis. | Active. |
| John Y. Bayliss, Guayaquil, Ecuador, S. A | " |
| Edward J. Fucik, Chicago | Junior. |
| Joseph Wright, Sheffield, Ill. | Active. |
| H. C. Holthoff, Milwaukee, Wis. | " |
| Louis Elliott, Chicago | Junior. |
| Chas. H. Rogers, Chicago | Active. |
| John C. Sample, Chicago | " |

The following list of new applicants was also presented:

| | |
|---|---|
| James Spelman, Chicago | Active. |
| N. Clifford Ricker, Urbana, Ill. | " |
| Jas. C. Grey, Chicago. | " |

| | |
|---|---|
| Thos. S. Leake | Associate. |
| A. H. Aldinger, Hinsdale, Ill. | Junior. |
| E C. Hasselfeldt, Chicago | " |
| Chas. J. Luck, Chicago | Active. |
| Carlton F. Moore, Houghton, Mich | " |
| John F. Jackson, Houghton, Mich | " |
| Wm. G. Sloan, Pittsburgh, transfer from Junior to | " |
| Wm. G. Langenheim, Chicago | " |
| Richard H. Heine, Chicago | " |
| John L. Hall, Chicago | " |
| Ernest Gonzenbach, Wheaton, Ill | " |
| Owen T. Smith, Freeport, Ill | " |
| Andrew Neureuther, Peru, Ill | " |
| Chas. L. Krum, Chicago | " |

There were no reports presented from the Standing or Special committees, excepting a report of progress from the committee on a legal standard of length for Chicago, which was as follows:

*To the Western Society, Gentlemen:*

"The committee appointed by the President of this Society to look into the subject of mural or bench standard of length for the City of Chicago and the County of Cook begs leave to report progress, as follows:

"The committee, consisting of Messrs. Geo. H. Bremner, A. C. Schrader, T. L. Condron, Peter Heer and John Ericson, had its first meeting on Saturday, April 12, with all members present, and organized with Mr. John Ericson as Chairman.

"There was a general discussion as to whether a bar or a tape standard was preferable, but no action was taken, as it was deemed advisable to obtain some further information on the subject, and such information has been sought by communicating with Mr. S. W. Stratton, Director of the National Bureau of Standards, Treasury Department, Washington, D. C.

"A sub-committee, consisting of Messrs. Condron and Ericson, was appointed to look into the matter of location.

"A second meeting was held on May 3, at which meeting the sub-committee above referred to reported through Mr. Ericson that they had visited the Public Library, the Art Institute and the new Postoffice building, and that the new Postoffice seemed to be the most suitable building for the location of the proposed standard. The sub-committee was instructed to enter into communication with the proper authorities for the purpose of securing the proper space in this building; also to seek the coöperation of the local United States engineers in the securing of this proposed standard, as well as the space referred to. In view of the expected visit of Director Stratton to this city and to our Society, no further action was taken.

"(Signed) JOHN ERICSON, *Chairman.*"

There being no other business before the Society, Past-President L. E. Cooley, in a few fitting and acceptable words, introduced to the Society Prof. S. W. Stratton, Director of the National Bureau of Standards, Treasury Department, Washington, D. C., who addressed the Society on the work of the National Bureau of Standards. Lantern-slide illustrations showed the buildings as planned and under construction.

Discussion followed from Messrs. L. E. Cooley, Bley, Schaub, Seddon, Milligan, Hatch, Schrader, Bremner, Abbott, Liljencrantz and Clarke.

Mr. Liljencrantz moved a vote of thanks to Prof. Stratton for his admirable presentation of the subject, which was carried.

Mr. Seddon offered a motion, which, after amendment, was seconded by Mr. Liljencrantz, that, on account of the importance of this question of the adoption of the metric system and the value that would follow from an endorsement of the measure now before Congress by the Western Society of Engineers, the Board of Direction be asked to consider the matter and to formulate a resolution and memorial to the Washington authorities, which resolution and memorial are to be presented at the next regular meeting of this Society for action.

The meeting adjourned about 10:30 p.m.

## LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the Journal for February, 1902, we have received the following gifts from the donors named:

Prof. D. C. Jackson, Madison, Wis., "Elementary Electricity and Magnetism." Cloth bound volume.
E. Farcot, Paris, pamphlet, "Trade Catalogue of Fans and Ventilating Apparatus."
F. L. Hill, Marquette Building, Chicago, "Devore's Multiplicandum," &c.
R. P. Brown, Chicago, by purchase—
  Cloth bound books, "Strains in Framed Structures," by A. J Dubois.
    " " " "Hydraulic Lifting and Pressing Machinery," by Fred. Colyer.
    " " " "Pumps and Pumping Machinery," by Fred. Colyer.
    " " " "Manual of Civil Engineering," by W. J. M. Rankin.
Prof. A. N. Talbot, Champaign, Ill., one volume, flexible morocco, "The Railway Transition Spiral."
Chas. D. Wolcott, Director, U. S. Geological Survey, Department of the Interior, one volume, cloth, Monographs, Vol. XL, 1900.
  " " Pamphlet, No. 177, Catalogue and Index of the publications of the U. S. G. S., 1880-1901.
  " " Pamphlet, No. 178, El Paso Tin Deposits, 1901.
  " " Pamphlet, No. 180, Occurrence and Distribution of Corundum in the United States, 1901.
  " " Pamphlet, No. 181, Results of Primary Triangulation and Primary Traverse, 1900-1901.
  " " Pamphlet, No. 183, A Gazetteer of Porto Rico, 1901.
  " " Pamphlet No. 184, Oil and Gas Fields of the Western Interior and Northern Texas Coal Measures, and of the upper Cretaceous and Tertiary of the Western Gulf Coast, 1901.
  " " Pamphlet, No. 185, Results of Spirit Leveling, 1900-1901.
  " " Pamphlet, No. 186, On Pyrite and Marcasite, 1901.
  " " Pamphlet, No. 187, Geographic Dictionary of Alaska, 1901.
J. T. Rodda, Eastbourne Water Works Co., England, one cloth bound volume, "Notes on Water Supply," etc.
U. S. Commissioner of Education, Washington, D. C., one volume, cloth, Annual Report, 1899-1900, Vol. II.
Goheen Mfg. Co., Canton, Ohio, trade pamphlet, "The Story of Human Progress," 1902, record of use of carbonizing coating (paint).
U. S. Dept. of Agriculture, Weather Bureau, pamphlet, "Loss of Life in United States by Lightning."
E. E. R. Tratman, Chicago, pamphlet, "Anthracite Coal Operators' Association," November, 1897, Mechanical Haulage by Compressed Air.
American Stoker Co., Chicago, Trade Catalogue, "American Underfeed Stoker."
Board of Water Commissioners, Detroit, pamphlet, Forty-ninth Report of Detroit Water Works, 1901.
J. H. Warder, cloth bound volume, "The Sterling Water Tube Boiler," 1895.
  " " " " " "The Zell Safety Boiler," 1894.
T. C. Pennington, Sec'y, nineteen pamphlets, 1st and 3d to 20th inclusive, annual reports, 1882-1901, American Street Railway Association.
Minister of Public Works, Argentine Republic, pamphlet, "Boletin de Obras Publicas de la Republica Argentine," April and June, 1901.

E. L. Corthell, Buenos Ayres, S. A., pamphlet, Specifications for Testing of Portland Cement.

Peter Milne, Sec'y American Water Works Association, pamphlet, "Legal Decisions," October, 1899, to April, 1901, inclusive.

Lathbury & Spackman, Philadelphia, cloth bound volume, "The Rotary Kiln," for cement manufacture.

C. L. Strobel, Chicago, one volume, paper, Vol. XXXVII, Transactions A.S.C.E., June, 1897.

Royal Engineers' Institute of England, cloth bound volume, Professional Papers, Vol. XXVII, 1901.

U. S. Civil Service Commission, seventeenth report, July, 1899, to June, 1900. Cloth bound.

C. L. Strobel, Chicago—
17th Report U. S. Civil Service Commission, July, 1899, to June, 1900.
18th Annual Report Department of Public Works, Chicago, 1893.
20th " " " " " " 1895.
42d Annual Statement, Department of Finance, Chicago, 1898.
Report Sewerage Commissioners, City of Baltimore, 1897.

L. C. Fritch, Sec'y American Railway Engineering & Maintenance of Way Association, Bulletins No. 15 to 27, inclusive, February and March, 1902.

Roadmasters' and M. of W. Association, pamphlet, Proceedings 19th Annual Convention, October, 1901.

University of Montana, pamphlet, Bulletin No. 3, Summer Birds of Flathead Lake, 1901.

B. E. Fernow, New York State College of Forestry, pamphlets—
Fourth Annual Report, 1901.
Twelve Theses on College Forest Management.
Adirondack Forest Problems, 1902.
Testimony Before the U. S. Industrial Commission in Forestry Matters.

D. Van Nostrand Co., New York, cloth bound volume, "Power Transmitted by Electricity," by Philip Atkinson.

R. D. Wood & Co., Philadelphia, pamphlet, Trade Catalogue, "Centrifugal Pumps."

New York Railroad Commissioners, two volumes (I and II), cloth, Report for 1901.

H. E. Back, Bureau of Labor Statistics, Connecticut, cloth bound volume, 7th Annual Report, 1901, Pub. Doc. No. 23.

Glacier Metal Co., New York, pamphlet, Glacier Anti-friction Metal.

A. J. Hammond, City Engineer, South Bend, Ind., pamphlet, First Annual Report, Department of Public Works, Dec. 31, 1901.

Capt. Lansing H. Beach, U. S. Engineer Department, Washington, D. C. four pamphlets, Reports of Operations Engineer Department, District of Columbia, 1898, 1899, 1900, 1901.

British Association of Water Works Engineers, cloth bound volume, Vol. VI, Transactions for 1901.

John P. Force, Columbus, Ohio, pamphlet, The Legal and Sanitary Aspects of Sewerage Construction.

W. F. Hall Printing Co., Chicago, one book, bds., "A Book of Printing Types."

New York-Continental-Jewell Filtration Co., Chicago, pamphlet, "Filtration at Lorain, Ohio."

J. B. Henderson, Hydraulic Engineer, Brisbane, Australia, pamphlet, 17th Annual Report on Water Supply, 1901.

J. B. Lippincott Co., Philadelphia, cloth bound book, "Solar Energy," by Heysinger. 1901.

Wm. S. Aldrich, Director "Thomas S. Clarkson Memorial School of Technology," Potsdam, N. Y., Catalogue, 1901-1902.

T. L. Condron, Chicago, Vol. XVIII and XIX, 1900, "Municipal Engineering."

Chief of Engineers, War Dept., two books, cloth, Report for 1901, Parts 3 and 4.

Otis F. Clapp, City Engineer, City of Providence, R. I., pamphlet, Annual Report for 1901.

The "Long Arm" System Co., Cleveland, pamphlet, Bulletin No. 5.

Bradley Pulverizer Co., Boston, pamphlet, "The Griffin Mill."

University of Tennessee, pamphlet, U. of T. Record, Vol. IV, No. 4.

Eastwood Wire Mfg. Co., Belleville, N. J., pamphlet, Catalogue "C," No. 900.

Ft. Wayne Electric Works, Ft. Wayne, Ind., two pamphlets, Bulletins No. 1020 and 1021.

Interstate Commerce Commission, pamphlet, Preliminary Report on Income Account of Railways in the United States, June 30, 1901.

National Association of German-American Technologists, two pamphlets, The Technologist, Vol. VII, No. 5, March, 1902.

North Carolina State Horticultural Society, Southern Pines, N. C., pamphlet, "Origin and History of the Cow Pea."

A. H. Funke, 101 Duane St., New York, pamphlet, "Baldwin Acetylene Lamps."

Metropolitan West Side Elevated Ry. Co., pamphlet, Report of Board of Directors to the Stockholders for the Year Ending Feb. 28, 1902.

Pittsburgh Gage & Supply Co., Pittsburgh, trade pamphlet, "White Star Filtering System."

Chicago Pneumatic Tool Co., Chicago, pamphlet, Trade Catalogue No. 16.

Allis-Chalmers Co., Chicago, three pamphlets, Trade Catalogue Nos. 24 and 54, and Circular No. 101.

C. W. Hunt Co., New York, pamphlet, Boston Elevated Ry., "How Coal is Handled."

Brookline (Mass.) Water Board, pamphlet, Report for Year Ending Jan. 31, 1902.

Illinois Association of Public Accountants, pamphlet, "The Duties and Responsibilities of the Public Accountant."

J. E. Sherman, Sec'y Marquette Light & Power Commission, pamphlet, "Annual Statement, City of Marquette, for the Fiscal Year Ending March 11, 1902."

Commissioners of Water Works, Cincinnati, one volume, cloth, Fifth Annual Report, 1901.
Secretary's report, "Engineer's Club of Cincinnati," 1901.

L. N. Case, Sec'y Water and Light Department, City of Duluth, Minn., Third Annual Report, 1901.

J. R. Thompson, City Engineer, Mankato, Minn., "Annual Reports City Engineer, Superintendents of Parks and Health Officer," 1901.

U. S. Department of Agriculture, pamphlet No. 136, "Earth Roads," by Maurice O. Eldridge.

Clifford Richardson, Society of Chemical Industry, pamphlet, Report Sub-Committee on Uniformity in Analysis of Materials for the Portland Cement Industry, January, 1902.

Board of Public Works, Little Falls, N. Y., Seventh Annual Report, 1901.

City Engineer, Milwaukee, Wis., fifteen pamphlets, Annual Reports, 1875-1900, inclusive.

Engineering News Publishing Co., New York, one volume, morocco, "Marshall's Logarithmic Tables," 1902.
One volume, morocco, "The Railway Transition Spiral," Talbot.

Report on Chicago Drainage Canal by the Committee Appointed by the Mayor of St. Louis, Mo., 1899.

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J. M. Sweeney, Mgr. Steel Cable Engineering Co., Chicago, pamphlet, "Mechanical Methods Handling and Conveying Coal, Coke, Ashes, Ore, etc."

H. I. Budd, State Commissioner of Public Roads, New Jersey, one volume, cloth, Eighth Annual Report, 1901.

## BOOK NOTES.

**Municipal Administration.** By John A. Fairlie, Ph. D., Assistant Professor of Administrative Law at the University of Michigan. Published by the Macmillan Company, 66 Fifth avenue, New York, N. Y. Cloth, 8vo., 448 pages. Price, $3 (19 cents postage).

This country is badly in need of an improved general system of municipal government, and it is somewhat discouraging to note the lack of interest displayed by the people as a body in the improvement of present conditions and the means of developing such improvement. Good literature on the subject is one of the important aids towards the improvement, with men who will not only study it but profit by and practice its teachings, and the book here reviewed is a notable addition to literature of this character. It presents the economic side of municipal administration and municipal engineering, and to the engineer the book is of practical interest, as his work lies largely in connection with municipal development, the streets, sewers and water supply, sewage disposal, street cleaning, local transportation, and numerous other features. He should also be interested, as a citizen, in municipal development generally.

The book is divided into four parts. Part I is devoted to "Municipal History," and commences with the cities of antiquity and the mediæval times; it then discusses the development of the English boroughs, the modern cities of France and Germany, and has a chapter on municipal development in the United States. This latter shows a striking growth and completeness of provisions for public welfare and safety, although the administration is marred throughout by partisanship, petty politics, and the spoils system, the administration being controlled rather by party or political considerations than by those relating to the best interests of the municipality or its people. Mr. Fairlie considers that future development will be upon the lines of a further separation of municipal from state and national elections, and a more efficient and permanent subordinate service.

Part II, on "Municipal Activities," is of particular interest to engineers and public officers. The first chapter treats of police, fire, health and building departments, and various officials; comparing the practice of different American and foreign cities, and setting forth the advantages and disadvantages in the several cases. Two chapters discuss public charities, provident institutions, schools, libraries, museums, etc. Two chapters (covering some 90 pages) are devoted to municipal improvements; streets, sewers and sewage disposal, bridges, water supply, parks, docks, markets, lighting, transportation, etc. Here also the actual practice of foreign and American cities is described, compared and criticised. The question of municipal ownership is also discussed, and the points in favor of both municipal and private control are set forth more clearly and fairly than is usually the case in discussions of this important subject.

Part III, on "Municipal Finances," discusses municipal expenditures, debits and revenues, and the question of finance administration. The three principal divisions in this latter question are the formation of the budget, the assessment and collection of revenues, and the systems of auditing and controlling disbursements.

Part IV, on "Municipal Organization," treats of the council, the administrative officials and the mayor, with their relations and authority under different systems. The last chapter is devoted to a discussion of proposed plans of municipal organization, and is a fit conclusion to the previous chapters, which show the great variety of form of organization existing not only in different countries, but more particularly in the various states and cities of the United States. A general scheme of municipal organization which has been adopted by the National Municipal League is described.

The book as a whole is a valuable addition to literature on municipal development, and is not only useful for study and for reference, but is also written in such a way as to be extremely interesting. E. E. R. T.

**The Science of Mechanics.** A critical and historical account of its development, by Dr. Ernst Mach, Professor in the University of Vienna. Translated from the German by Thos. J. McCormack. The Open Court Publishing Co., Chicago. 605 + XX pages. 259 cuts and illustrations. Cloth, $2.00.

The subject of mechanics is so generally treated in the text-book form and phraseology that readers will find relief in pursuing this branch of learning as it is presented by Dr. Ernst Mach in this translation from the German of the fourth edition of his work.

Rather than to compile and classify established formula, the author traces the development of mechanics, both historically and with reference to its logical evolution from primitive observation, and draws a sharp distinction between "mechanical experience" and "mechanical science."

Science is defined as the "Economy of Thought," and in this instance is such a formulation and classification of deductions and parallels from actual experiment as to establish certain so-called principles which may be relied upon by the most conscientious searchers after mechanical truth, without repeated attempts at redemonstration.

The reader is impressed with the laborious efforts set forth of the many great minds that have sought to prove by a mental logic so much that is seemingly axiomatic, and the question will arise as to the expediency of such great effort in this direction.

The author discusses instinctive knowledge and states that, no matter how useful it may be in the processes of development, it must give way to the clearly observed principle.

The conclusion seems to be that instinctive knowledge is, after all, only experimental knowledge which is liable to prove insufficient when new regions of experience suddenly appear.

The most that we can do is to accept for the time being what *is* or seems to be under immediate conditions.

The author claims that it is beyond the ken of man to know what effect one body would have upon another if they were the sole and only bodies in existence, for no such condition has been or could be observed. Thus in statics, "termed the doctrine of equilibrium," the reader must be confidently content that, "when nothing can happen, nothing does happen."

The experiments and deductions of Archimedes, Galileo, and many others down to the time of Newton, are interestingly and clearly set forth. The author takes exception to Newton's investigations where it is claimed they attempt to extend beyond "actual fact," and states that no one is competent to predicate concerning "absolute space" and "absolute motion."

Not the least interesting is the latter portion of the book where the theological, animistic and mystical points of view in mechanics are discussed and the relative historical facts cited. The deductions seem to warrant the belief that theology and physics are quite distinct. T. C. I.

**The Railway Transition Spiral.** By Arthur N. Talbot, Mem. Am. Soc. C. E.; Professor of Municipal and Sanitary Engineering, University of Illinois. Third edition, revised. Engineering News Publishing Co., New York. Cloth, 4¼x6¾ inches, 110 pages; with diagrams and tables. Price $1.50.

This is one of the latest books on a subject whose importance is now generally recognized, and it is of particular interest at this time when so many railways are improving their alinement. The spiral here presented is a flexible easement curve of general applicability and of comparatively easy analysis, the general methods and field work of which are quite similar to those for ordinary circular curves. This spiral is already in extensive use on a number of railways. The principles and their application to various problems are clearly explained, and a specially interesting feature is the discussion of the use of spiral curves for street railways, with a table for this class of work. The book is well printed in large type, and is of very convenient size. T.

**Logarithmic Tables of the Measures of Length.** By Thos. W. Marshall. Engineering News Publishing Co., New York. Flexible leather, oblong, 5¾x3¼ inches. $2.00.

These tables pertain to linear measurements of feet, inches and fractions by sixteenths for a range of 0 to 50 feet, the logarithmic value to seven places of decimals being given for each.

To those engaged in much computation, involving mixed lengths, these tables should be of value. The typographic execution of the book is good. The tables are arranged with six vertical columns on each page, so for a double page each succeeding column represents an advance of one inch over the preceding column. The horizontal lines are sixteen in number and on each margin of each page is indicated the increasing notation of sixteenths. The figures of the logarithms themselves are clear and well arranged, to be easily picked out by the user. Three pages of introduction serve to refresh ones memory of the use of logarithms, and show the economy of time when making calculations by the use of such tables. W.

**Stadia Tables, for obtaining horizontal distances and differences of level from Stadia Reading.** Computed by Alfred Noble and W. T. Casgrain. Engineering News Publication Co., New York. Cloth, 4½x7 inches, 47 pages. $1.00.

**Topographical Record and Sketch Book, for use with Transit and Stadia.** D. L. Turner, C. E. Instructor at Harvard University. Engineering News Publication Co., New York. Stiff linen covers; 5½x7½ inches. 92 pages. 75 cents.

The value of stadia work in surveying is more and more recognized, and some good articles on this subject have appeared from time to time in the pages of this JOURNAL. Of the above books, that by our past president, Mr. Noble, first appeared some years ago, but is now brought out in a new edition. The introduction explains the use of the stadia for various parts of field work in surveying, which the tables following in the body of the book supplement. The tables are well printed and easily read.

The second book noted above is a necessary sequence to the book of tables. It is a blank book, made of good linen paper and of a size to be carried by the engineer in his pocket. The left hand page is ruled (in blue) with horizontal lines and vertical columns for the recording of the stadia notes. The right hand page is ruled with concentric circles ¼ inch apart and radial lines at 10-degree intervals for assistance in sketching in topography, pertaining to the record of the opposite pages An introduction of three pages will be an assistance to the young engineer in the use of this note book, which should prove of value in his field work. W.

**Water and Its Purification.** By Samuel Rideal, London. J. B. Lippincott & Co., Philadelphia. 8vo, 346 pages, 66 illustrations, and copious index. Cloth, $3.00.

Mr. Rideal, well known in this country for his important work on Sewage published in 1900, has now added another valuable volume on Water Purification, which covers recent English practice in somewhat the same manner as Whipple, Mason and Nichols have in this country.

Mr. Rideal has, perhaps, little that is new to add to the subject, considering the vast amount of information that has been recently published, but his book is chiefly valuable in that it gives us a brief and comprehensive review of such studies in England. His work is strong in all that relates to the characteristics and analyses of different waters, as might be expected from one who was himself so thorough and efficient a chemist and bacteriologist. There is, strictly speaking, no attempt in this volume to consider the subject from its engineering side, but the question of pure water supplies for English cities and under English practice is pretty thoroughly gone into.

The chapter on Water Purification is somewhat brief for so large a subject, but in the main gives a pretty clear idea of the studies on filtration at the present day, and it is notable that on this subject quotations from American engineers and scientists are freely made, showing that the value and importance of the work done on this side of the water is fully appreciated by our English cotemporaries.

The chapter on Household Water Purification and another chapter on Water Softening are valuable and interesting and apparently full of the results of the author's personal experience. Perhaps no part of the book, however, is more valuable than the chapter on analyses and its results, which gives clearly and distinctly the author's methods and interpretations of water analyses, a most important subject and one that is not always fully understood, even by many professional men.

Perhaps no part of the subject of water purification is so difficult to adequately deal with as this subject of the interpretation of analyses. Most professional men are familiar with the ordinarily expressed form of analyses, both chemical and bacteriological, but the majority of those who find it necessary to use such methods for determining the purity of water, place undue stress upon the measured determinations, to the exclusion of all other surrounding circumstances. In vain do chemists and bacteriologists from time to time point out to us that there is no very definite line between pure and impure water, and that a great number of circumstances should be carefully taken into consideration before a verdict is rendered either for or against a specific sample. But that tendency of human nature which invariably seeks to arrange itself upon one side or the other of a question makes it difficult to refrain from fastening on to some dividing line which shall distinguish in all cases and under all circumstances the good from the bad

Mr. Rideal has rendered a service in reiterating the fallacy of this position, and insisting upon the broadest kind of interpretation of chemical and bacteriological results, regardless of numerical or technically expressed determinations.

To all those who are interested in the subject of pure water supply, Mr. Rideal's work will be a valuable help, and it is so clearly written that even the non-professional reader will find it a valuable and interesting acquisition to his library.

J. W. A.

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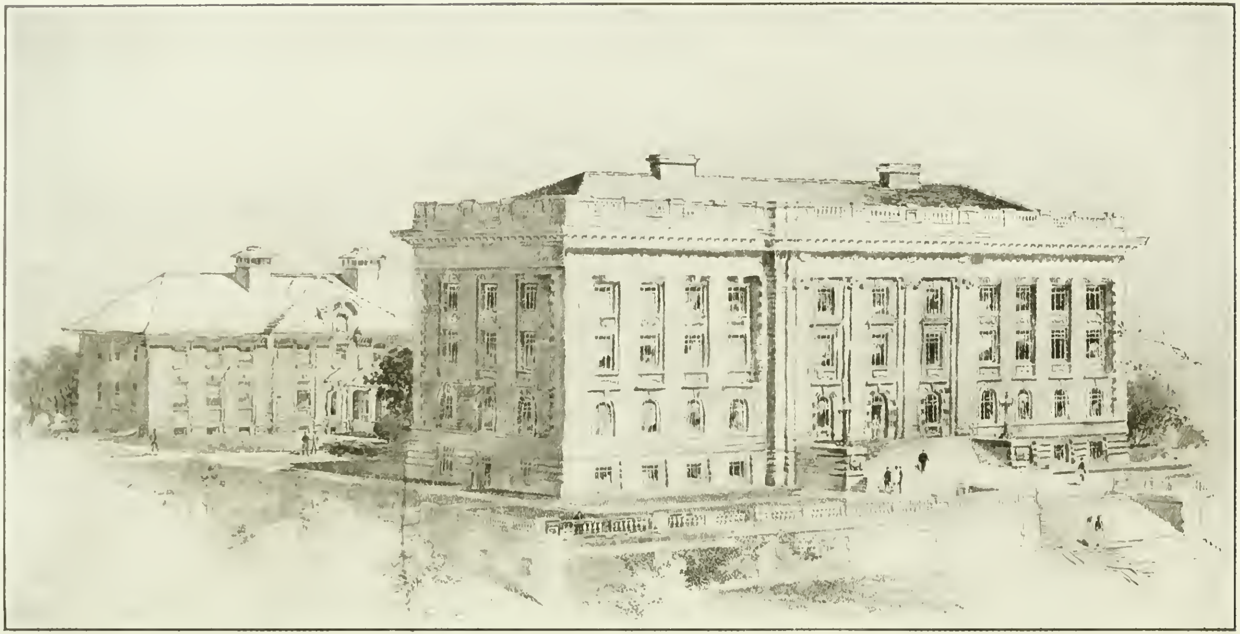

THE BUILDING FOR THE NATIONAL BUREAU OF STANDARDS
JAS. K. TAYLOR, SUPERVISING ARCHITECT

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## CXLIX.

## THE NATIONAL BUREAU OF STANDARDS.

By Prof. S. W. Stratton, Director of the Bureau, Washington, D. C.

*Presented May 8, 1902.*

The necessity for uniform and reliable standards is a subject which has long claimed the attention of our foremost statesmen and scientists. Washington repeatedly urged upon Congress the necessity for uniform and reliable standards, and in his third annual message to Congress stated that "an improvement in the weights and measures of the country is among the important objects submitted to you by the Constitution, and if it can be derived from standards at once invariable and universal, may be not less honorable to the public councils than conducive to the public convenience." Thomas Jefferson, then Secretary of State, was directed by Congress to report upon this subject, and after a most careful consideration submitted a report in which he outlined two alternative plans, one based upon the retention of the then existing standards, fixing them, however, by some invariable standard; the other a decimal system based upon the length of a pendulum beating seconds. President Madison in 1817, reminded Congress that nothing had been accomplished in reforming and unifying the system, whereupon the whole subject was referred to John Quincy Adams, then Secretary of State. Mr. Adams gave four years of historical research and mathematical study, and prepared a report which has become a classic in metrology, but which advised delay until the time when nations had agreed on a universal standard and the subject had received more attention.

Notwithstanding these efforts and the reports of various individuals and committees, Congress has never exercised the power delegated to it by the Constitution, with the exception of an Act of May 19, 1828, relative to the adoption of a troy pound as a standard to be used in the coinage of money; the language of which is as follows: "For the purpose of securing a due conformity in weight of coins of the United States to the provisions of this title, the brass pound weight procured by the Minister of the United

States at London, in the year eighteen hundred and twenty-seven, for the use of the mint, and now in the custody of the mint at Philadelphia, shall be the standard troy pound of the mint of the United States, conformably to which the coinage of the United States shall be regulated."

Previous to this, by an act passed in 1799, it was ordered that "the surveyor of each port of the United States shall from time to time, and particularly on the first Monday in January and July in each year, examine and try, the weights, measures, and other instruments used in ascertaining the duties on imports with standards to be provided by each collector at the public expense, and when disagreements or errors are discovered, he shall report the same to the collector, and obey and execute such directions as he may receive for the correction thereof, agreeably to the standards aforesaid." Apparently this act was not enforced, probably for the reason that no standards had been adopted by Congress or by the Treasury Department. On May 29, 1830, the Senate passed a resolution directing the Secretary of the Treasury to have an examination made of the weights and measures in use at the principal custom houses. The duty of making the examination was intrusted to Mr. F. R. Hassler, Superintendent of the United States Coast and Geodetic Survey, who was at that time the only man of recognized scientific attainments in the employment of the Treasury Department. Mr. Hassler, under date of January 27, 1832, reported that he had found large discrepancies among the weights and measures in use. He was thereupon directed by the Secretary of the Treasury to secure apparatus and establish a shop, wherein copies of certain standards adopted by the Treasury Department could be made for distribution to the various custom houses. The avoirdupois pound adopted was derived from the troy pound of the mint and the distance between certain lines on a metal bar in the possession of the department and supposed to conform with the English yard was taken as the standard of length.

In June, 1836, Congress passed the following resolution: "Resolved, That the Secretary of the Treasury be, and he hereby is, directed to cause to be made, a complete set of all the weights and measures adopted as standards, and now either made or in progress of manufacture, for the use of the several custom houses or such persons as he may appoint and for the use of the states respectively, to the end that a uniform standard of weights and measures be established throughout the Union."

On July 27, 1866, the following joint resolution was adopted: "Be it resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be and he is hereby authorized and directed to furnish to each state, or to be delivered to the governor thereof, one set of standard weights and measures of the metric system for the use of the states respectively." Here again the selection of the standards necessary to carry out the foregoing resolutions was left to the Secretary of the Treasury, who procured from abroad copies of the original metric standards.

Since that time, Congress has provided for the construction and verification of the standard weights and measures of the custom houses of the United States and for the several states. The custody of the standards adopted by the Treasury and the carrying out of the provisions made by Congress remained until July 1st, 1901, under the direction of the Superintendent of the Coast and Geodetic Survey, who served also in the capacity of the Superintendent of the office of Standard Weights and Measures.

In 1866, the metric system, while not adopted by Congress, was made lawful throughout the United States, but the standards of this system were not yet satisfactory, and in 1875, more than half a century after Adams had recommended a conference between nations for the purpose of establishing a world-wide uniformity in standards, such a conference was held, and as a result there was established in Paris a permanent International Bureau of Weights and Measures. Scientists were engaged for several years in perfecting prototypes of metric standards, and in 1889, these were ready for distribution among the seventeen nations represented in the international conference. So important were considered the details of bringing the standard meter and kilogram to the United States, that the department sent special commissioners abroad for the purpose of conveying these valuable standards from Paris to Washington. They were opened at the White House in the presence of the President, the Secretary of State and a distinguished company of scholars. These standards were then placed in the custody of the office of Standard Weights and Measures and are now used as the basis of all comparisons of mass and length in this country, even in the common system. There is at the present time no satisfactory standard yard in the possession of the government. The early standards procured by the Secretary of the Treasury are so poorly constructed and the lines so broad that a more accurate yard may be made by means of the standard meter. Troy and avoirdupois pounds submitted for inspection are tested with metric weights or with standards which have been derived from the standard kilogram. That is to say, the standard meter and kilogram are so well constructed that more accurate standards in our common system may be produced in this manner than by comparison with any standard pound or yard in existence.

It has been seen that, until very recently, the provisions made by Congress covered only the common measures of weight, length and capacity. The facilities of the office of Standard Weights and Measures were exceedingly limited, and the exercise of its functions confined to departments of the general government and the states. The set of standards furnished each state consisted originally of the most ordinary standards of length, weight, and capacity. Later a few metric standards were added to these, but in few instances have the states provided facilities for the proper comparison and use of these standards by the general public. In some states the standards have been destroyed or lost track of, and we find little legislation pertaining to weights and measures, other than to fix the number of pounds to the bushel, to be used in measuring grain and other produce. An investigation carried on last summer by a government official disclosed a condition of affairs in regard to the common weights and measures of the country that would hardly bear publication. The duties of state and city sealers should include the testing of water and gas meters and perhaps, eventually, electric meters, but certainly all of these standards and measuring instruments in common use by the people. And it is the duty of the general government to provide such officers with suitable standards, measuring instruments, and instructions governing their use.

The progress of science, and the employment of exact scientific methods, by the great industrial and commercial enterprises, have brought about conditions which demand a radical change in matters pertaining to standards. Whatever may be said as to the necessity of improvement in the common measures of weight, length, and capacity, is equally true of the more accurate measurements of these same quantities as applied to scientific investigations, in the laboratories of our educational institutions, scientific societies, and manufacturing establishments, interests which demand for the successful completion of their work standards of the very highest order of accuracy. The public interest demands a far greater variety and range of standards than heretofore, such as those used in the measurement of high and low temperatures, pressure, standards of illumination, electrical standards of resistance, current, electromotive force, capacity and self-induction, polariscopic, barometric, and many other standards. In many cases, the problems involved are difficult and complex, and reliable standards difficult to procure. The examination and comparison of standards requires the use of the most delicate instruments known to science, under the most advantageous conditions as to temperature, freedom from vibration, and laboratory conveniences.

In recent years, the demand for accurate scientific standards and in many cases commercial standards has been met by standardizing institutions of foreign governments. Frequently the benefits to be derived by the public from fixed and reliable standards are through the medium of a great variety of meters and precise measuring apparatus, such as balances, apparatus for measurement of lengths, capacity, graduated glassware, pressure gauges, thermometers, barometers, metrological apparatus, pyrometers, gas and water meters, voltmeters, ammeters, wattmeters, oil testers, the instruments used in surveying, navigation and hydrography; apparatus for testing the strength of materials, and many other instruments. That the graduations and indications of these instruments should agree with the fundamental standards, is a question of the most vital importance; and without the facilities for such tests and comparisons, the public is deprived of the greatest benefits to be derived from such standards as may have been recognized by the government.

The manufacture of physical, astronomical, chemical, and other scientific apparatus has been confined almost exclusively to foreign countries—but this industry is growing in the United States at a rate which will soon place our production on an equality with that of any other country. Our manufacturers of such apparatus have shown that they can compete with the foreign products in workmanship and design. They have, however, been placed at a great disadvantage, owing to the fact that this government has not provided them with the necessary standardizing facilities. German and English manufacturers furnish official certificates with their apparatus, and the value of such certificates is so well recognized that we find our own manufacturers quoting prices on their apparatus which has been verified in the institutions of foreign governments.

It was this condition of affairs that led Congress to enact a law March 3, 1901, establishing the National Bureau of Standards, the functions of which include the custody of the official standards, and comparison of all standards used in scientific investigations, engineering, manufacturing, commerce, and in educational institutions, with the standards adopted or recognized by the government; the construction when necessary of standards, their multiples and sub-divisions, the testing of standard measuring apparatus, and the solution of problems which arise in connection with standards. It is also authorized to make physical and chemical researches for the purpose of determining physical constants, and the properties of materials when such matters are of great importance to scientific or manufacturing interests. The Bureau is authorized to exercise its functions for the departments of the government, for any state or municipality within the United States, scientific society, educational institution, firm, corporation, or individual, engaged in manufacturing or other pursuits requiring the use of standards, or standard measuring instruments.

A suitable site has been purchased by the government in the northwestern suburbs of Washington, just beyond Cleveland Park, a locality free from mechanical and electric disturbance. Plans are being prepared for a physical laboratory, which will be equipped with apparatus and conveniences for carrying on investigations and the testing of standards and measuring instruments of all kinds; also a building to be known as a mechanical laboratory, which will contain the power and general electrical machinery, the instrument shop, refrigerating plant, storage batteries, dynamos for experimental purposes, and laboratories for electrical measurements requiring heavy currents.

These laboratories will be constructed immediately, but the plans are being made with reference to the future growth of the Bureau, which will soon become one of the most important scientific institutions of our government.

The value of such an institution has been clearly demonstrated by nearly every government of Europe. England has established a Standard Department of the Board of Trade, also the Electrical Standardizing Laboratory, and recently a physical laboratory. The Kew Observatory, an institution famous for its testing of meteorological instruments, has also become a government institution. Germany has established the Normal Aichungs Commission, with its laboratories and facilities for handling commercial weights and measures, —and in 1887, the Physikalisch-Technische Reichsanstalt, an institution costing more than a million dollars, which makes provision for scientific standards and investigations. It has been frequently said that this institution more than pays for itself annually in the assistance it gives to German engineers, manufacturers and scientists. The scientific work of our own government has received great benefit from this institution during recent years. At the hearing before the House Committee on Coinage, Weights and Measures, in reference to the Bureau of Standards bill, the Secretary of the Treasury presented letters from all the scientific bureaus in the government, stating that they were compelled to go to this institution for certain standards. There is scarcely an interest in the country which will not be vitally benefited by this new institution. Its relation to foreign commerce will be far-reaching and its establishment means that the United States has taken a long step forward in the international race for commercial supremacy.

This bureau will in time become something far more important and comprehensive than a mere standardizing institution. Our scientific and engineering laboratories are carrying on researches and investigations which are equal in value to those of any other country. It is not to be expected that an engineer or manufacturer can keep in touch with the scientific literature of this and other countries, and the scientist is too frequently unconcerned or prevented by a lack of time from the consideration of the practical applications of scientific work. There is no reason why this bureau should not eventually be a Bureau of Information where manufacturers and engineers may go for assistance and information along scientific lines. The progress of manufacturing and many commercial industries follows very closely the scientific development of the country. The government expends over a million dollars annually in maintaining an elaborate system of agricultural experiment stations throughout the country, in order that the agriculturist may have the benefit of scientific investigation. Why should not the manufacturer be assisted in the same way?

Whatever may be said of the advantages to be gained by the adoption of uniform and correct standards in any country, applies still more in regard to uniformity of standards between nations. The introduction of modern methods of transportation and communication have brought the countries of the world into closer relation than were the countics of Great Britain a century ago, and while the question of a universal system of weights and measures has been discussed for many years, the adoption of such a system has become a necessity at the present time. Scientists were compelled long ago to adopt a universal decimal system of weights and measures, in order to facilitate computation and the exchange of scientific knowledge. The meter and the kilogram were taken as the fundamental units of this system. It is very desirable that the fundamental units of any system be natural units, that is to say, fixed by some object or natural phenomenon, as for example, the unit of time is taken with reference to the earth's rotation. The meter was taken as the one ten-millionth part of the length of a meridian from the equator to the pole. Subsequent measurements of the earth's surface have shown that the meter, as constructed, is not exactly the length as defined, and this fact has sometimes been used as an objection to the metric system. This, however, is of little importance, since the meter and kilogram, as now constructed, are as permanent as it is possible to make material standards, and copies may be made far more accurately than may be derived from the most accurate measurements of the earth's surface. Hence it is needless to say that this is not only a weak objection but one never advanced by any one familiar with the subject of weights and measures, since, if at any time a better natural unit of length should be discovered, all that would be necessary in order to take advantage of it would be to define the meter in terms of this natural unit. In fact this has already been done. It has been found that the wave length of light, under certain conditions, meets many of the requirements of a natural standard, and the number of wave lengths to the meter has been determined, hence all that is necessary to produce a meter is to lay off this number of wave-lengths.

Another objection which has sometimes been urged against the metric system is the fact that it is not a binary system. Here again, the objection is purely theoretical, and a binary system of weights and measures in connection with a decimal system of numeration would be an absurdity. If the base of our system of numbers were eight or twelve, there might be some sense in proposing a sytem of weights and measures to correspond, but such will never be the case. The last of the objections commonly urged against the metric system is that of the expense and confusion brought about by a change in matters of such vital importance as weights and measures. The experience of other countries has shown that the inconvenience and expense has been greatly over-estimated, and that with a sufficient time allowed for making the change, it has been gradually and successfully made, with no serious expense or confusion. The longer the change is deferred the more difficult it will be to make.

The most serious objection to the change is that we have learned to think in the old system of weights and measures. Manufacturers, mechanics, tradesmen, consumers, and in fact all classes of people have learned to think in the old system. They have acquired experience as to sizes, quantities, and relations, and this experience is daily used in new business, new designs, and new relations. These mental comparisons are never exact measurements, but none the less important. The measurements which are made daily by the use of measuring instruments of all kinds are as readily performed in one system as the other. The trouble does not lie here, but with the mental measurements by which we compare new things with the old. Fortunately in this case, the difficulty is not nearly as great as those who are unfamiliar with the metric system would have us believe. There are in all cases, simple approximate ratios which will lighten the burdens of the transition stage. For example, the architect and builder have in mind the standard sizes of rooms, doors, windows, and other component parts of a building in feet and inches. This knowledge is used in new designs and new construction, but the simple approximate relations between the decimeter and the foot (three decimeters being very nearly equal to the foot), will enable him to translate feet and inches into decimeters without the slightest inconvenience. For example, a door which is

2 feet 8 inches by 7 feet, will be designed as 8 by 21 decimeters, and this will differ but very slightly from his previous designs. Where the engineer has in mind a one-inch shafting, the new design will be 25 millimeters. If the daily supply of milk has been 2 quarts, then 2 liters will answer the purpose, since it is but a trifle more. Coffee, tea, sugar and meats will be sold by the kilogram or kilo, and for each two pounds purchased before, one kilogram will be found a practical equivalent. A dress pattern which contained ten yards will be nine meters (i. e. one-tenth less). In navigation, the fathom is sufficiently near two meters to avoid danger in the interpretation of charts. With the draft of the vessel and the lead line marked in meters, it is difficult to see how any mistake could arise from charts marked in the metric system. These relations would serve for the purpose of mental translation. The measurements themselves would of course be made as heretofore with suitable instruments, such as meter sticks, balances, and capacity measures. In a comparatively short time, people would learn to think in the new system. The importance of these simple approximate relations cannot be over-estimated, since they will prove of great assistance in the translation of our past experience in the common system to our future needs in the metric system.

We must, I think, give all classes of people the credit for having a certain amount of intelligence and common sense, and in no country is the average degree of intelligence of the people so high as in this country to-day.

Careful estimates made by experienced educators, both in this country and in Great Britain, place the time saved by the adoption of the metric system from two-thirds to one year in the life of every school child; two-thirds of a year being the lowest estimate which has ever been given in an official investigation. Now this is a fact worthy of our deepest consideration, and the saving involved is enormous in comparison with the losses and inconvenience in other lines, especially when it is considered that those losses are but temporary and will be compensated by future advantages. We all know that arithmetic is the most difficult portion of nearly every child's school work, and that compound or denominate numbers is the burden of arithmetic. There is as much difference between arithmetic taught in the metric system and that in the common system as between the ease with which the tens and nines are learned in the multiplication table.

The Report of the Committee on Coinage, Weights and Measures of the House of Representatives concisely indicates some of the more important aspects of the subject, from which I shall quote briefly: "The scientific world to-day enjoys the advantages of a universal system of weights and measures, a fact which has greatly facilitated the development and spread of scientific knowledge. The practical applications of scientific work have in many cases been seriously handicapped or retarded, owing to the necessity of converting formulæ derived in the metric system to equivalent formulæ in the common system. If the formulæ and other data used in manufacturing and engineering were universally expressed in the metric system, it would greatly promote the growth and dissemination of such knowledge throughout the entire world." Speaking of the relation of the metric system to educational interests, the report states: "The benefits to be derived from the adoption of the metric system by the educational interests of the country are perhaps the most important that have been brought to the attention of this committee. Estimates made by the Department of Education and others show that the work of at least two-thirds of a year in the life of every child would be saved by the adoption of the metric arithmetic. When we consider that there are over 15,000,000 school children in the United States being educated at a public cost of not less than $200,000,000 per year, the enormity of the waste will be appreciated. In the lifetime of a single generation nearly $1,000,000,000 and 40,000,000 school years are consumed in teaching a system which is in harmony with that of no other nation of the world."

Referring to the relations to manufacturing interests, the report says: "It should be emphasized that this measure in no way contemplates any change in existing technical standards, such as screw threads, wire gauges, lumber measures, and numerous others, except as manufacturers and other interests find it to their own interest to make the change. Doubtless a change in the fundamental standards of length and mass would facilitate the simplification of such standards; but the changes would still be brought about as heretofore by the special interests involved. * * * The relation between the manufacture and the sale of these products is so close that any change in the system of weights and measures which will lessen the burden and expense of the counting-room and office is worth the cost, considered from the standpoint of economy alone. The action of many associations of manufacturers and merchants, both in the United States and Great Britain, has been called to our attention, and without exception they have urged the adoption of the metric system of weights and measures, on account of its international character and superiority over the present system for manufacturing and commercial purposes."

The report alludes to the system of interchangeable parts as a product of American ingenuity and characterizes it as the "greatest single advance in modern machinery," closing with the statement that "certainly an interchangeable system upon an international basis will be superior to one based on the standard of a single country."

Continuing, the report considers the commercial aspect of the new system. "The enormous development of the commerce of the United States within recent years has brought to the attention of our merchants and business men the great advantages to be derived from the adoption of an international system of weights and measures. The use of the old system not only involves great loss of time in making computations, but places our merchants at a great disadvantage in dealing with countries which have already adopted the international system. More than sixty per cent of our commerce is now carried on with countries using the weights and measures of the metric system, and it is evident that the commerce of the world must soon conform to the metric basis." The report quotes at length a letter from the president of the National Manufacturers' Association, urging in the most emphatic and convincing manner the adoption of the international system, and closing with the statement: "It seems to me that every argument is in favor of the unification of standards of weights and measurements throughout the world, and for us to insist upon an adherence to our antiquated standards is not in accord with the progressive nature of our people and the progressive tendency of this age." Mr. Cabot, a prominent New England merchant is quoted as saying: "Wherever this great improvement has gone, it has simplified the ordinary commercial transactions of daily life, minimized disputes, and given an absolute standard from which there could be no appeal, and in which there was the least possible danger of error or misunderstanding."

The committee found that "the necessity for improvement in the weights and measures of the country is nowhere more apparent than in the ordinary business transactions of daily life. Grain and produce are bought and sold by capacity measure, the bushel, peck and quart. The necessity for handling these commodities in large quantities by weight has resulted in the adoption of different weights for a bushel for the same commodity in different parts of the Union and in a few of the western states the hundredweight is used instead of the bushel. * * * The experience of other nations has shown that the confusion and inconvenience caused by a change in the measures used in daily life was largely over-estimated, and in no case have the people expressed a desire to return to the former system of weights and measures."

In concluding its report, the following statement is made: "In 1866, Congress legalized the metric system. From that time on it has been growing in favor and in practical use. It is here to stay, not only in scientific work, but in commerce and manufacturing.

It is now used by about two-thirds of the people of the world. Russia, Great Britain, and the United States are the only non-metric countries. Russia has gone so far in the direction of its adoption that it may well be excluded from the list, leaving Great Britain and the United States. In both of these it has been legal for some time. Indications are that Great Britain will soon join the list of metric countries. Over 300 members of Parliament have already signified their willingness to vote to make the use of the metric system compulsory. * * * Your committee believe the time has come for the gradual retirement of our confusing, illogical, irrational system and the substitution of something better."

### DISCUSSION.

*Mr. Bley*—I would like to ask what we are to understand by a "legal standard?"

*Prof. Stratton*—That question was submitted to the Attorney General, and his decision was that we could no more exclude the use of a particular system of weights and measures than we could exclude from use a particular language in writing.

The bill provides that the terms expressing weights and measures in all public documents shall be in the new system after January 1st, 1904.

A contract made for goods to be paid for in pounds, shillings and pence would be valid. If the kind of money was not stated, then I believe you could collect the sum of money in the legal standard; but a contract involving the payment for goods in pounds, shillings and pence is just as binding as if it were made in dollars and cents.

*Mr. James Seddon*—There are two government surveys, one expressed in meters and the other in feet. The adoption by the government of the metric system as its legal standard, I believe, is an action that everyone who has had occasion to deal with government work in a broad sense recognizes as highly desirable. The practice seems to be drifting toward the metric system, although I am not sure but that a better system may arise in the future. But it would certainly be very much to the advantage of those who are using different systems in government surveys, to have one universal system.

*Mr. R. E. Milligan*—I have been very greatly interested in Prof. Stratton's paper and am very glad to know that a change is being contemplated from the existing complicated standards. As a matter of fact the metric system has been used in chemical departments for a great many years, and it has been found necessary in almost every instance for the chemist to translate his results into the United States grains—so many grains to the gallon, instead of so many milligrammes to the liter. It is also a fact that it is almost impossible in this country to-day to find two burettes that will compare in discharge measurement; that is to say, two pipettes of the same manufacture, graduated in cubic centimeters, have to be regraduated by the chemist, and of course, having no standards to do it by, it necessarily becomes a matter of comparing. He makes his two pipettes to fit one to the other. If these be used by two chemists, in different parts of the country, necessarily their results do not agree, and it very often seems that the results of two chemists on the same work, in different parts of the country, differ very essentially, while as a matter of fact the difference is merely in measurement of capacity. I think that if the government, through this very valuable bureau, were to establish standards and standardize different scientific apparatus, it would be hailed as a great benefit to all departments of business involving chemical work. Also in some commercial lines there are some very curious discrepancies, and there should be no doubt as to the value of one standard of weights and measures. It is perfectly well understood by professional men that the only standard that is logical and the best is the metric system. Of course, it probably is not perfect, and may be succeeded in the future by some other better standard, but it is ahead of what we might call the "grain" system, when we consider the definition of a grain, viz.: "A grain is three kernels of wheat taken from the centre of the ear and well dried." One can readily see what a great difference there might be in a grain. I understand the government took three grains at one time and weighed them, and that all measurements have since been based on them.

If it is not asking too much, I should be glad to have Prof. Stratton explain what is the American basis for the American grain. We all know the derivative of the gramme, and its subdivisions into milligrammes, etc., are easy of computation and are perfectly legible.

In the matter of thermometers there is the greatest possible variation. There is really no standard thermometer in the country. The Fahrenheit thermometer is in more general use by the public. While on the witness-stand recently at Vincennes, I kept reciting certain temperatures in centigrades, and in every instance I was forced to convert them into Fahrenheit degrees for the enlightenment of the judge.

I think I voice the sentiment of every chemist in this country in favor of the use of the metric system, although it is very probable that in certain lines of work like draughting, etc., a radical change would cause a good deal of confusion. However, I understand from Prof. Stratton that it has nothing whatever to do with any radical change; that it is simply the use by the government of a more satisfactory standard than they have had heretofore, and it really must appeal to the people at large how sensible it would be to change to the metric system.

*Prof. Stratton*—I can say that this graduation of chemical apparatus is one of the first things to be done by the new bureau, and the graduation of thermometers is another; both of these pieces of work are pretty well under way. We are about to begin the calibration of chemical glassware and thermometers for the public.

The standard glassware can be obtained through the manufacturers—Whitall, Tatum & Co. They are manufacturing accurately graduated glassware. There are scientific gentlemen in this country who would not use glassware that did not come from Germany. A government certificate as to the accuracy of the home-made article will do much to correct this impression and encourage the manufacture and use of the home product.

*Mr. Hatch*—There is considerable work going on with the idea of making the wave length of light a unit of length is there not?

*Prof. Stratton*—The length of the meter has been determined in wave lengths of light, and that merely fixes it. If the meter should be destroyed at any time, it could be reproduced by laying off this number of wave lengths of light.

The government is provided with the standard meters made of platinum irridium alloy; one is put away and never used at all except in comparison with each other.

*Mr. A. C. Schrader*—The matter is being considered of placing a standard of length here in Chicago. I would like to know from Prof. Stratton what his idea is as to its graduation, and as to the proper method to be used; also the most suitable location.

*Prof. Stratton*—I was very much pleased to hear the suggestion to place this standard in the new post office building, and I think that is a matter that can be very easily arranged. If you can establish this standard, I should advise by all means the establishment of a bar or bench standard. This should be one-half inch thick and perhaps two inches wide; length, 100 feet; it should be supported on rollers about every three feet and should be a continuous bar. I think it could be procured at the rolling mills. You may have to bend it twice and then straighten it in place. But these are problems that can be very easily solved. About one-half inch from each edge should be a series of plugs—German silver or other suitable metal; one of these series is spaced for feet graduations and the other for meters. This bar being made of steel, questions of temperature are eliminated for steel tapes.

*Mr. Schrader*—Should the covering to protect this bar be of any special kind?

*Prof. Stratton*—An ordinary wooden cover will answer. It could be made in sections of eight or ten feet in length, so the sections could be turned back one at a time. We shall be glad to give specifications of the one that we propose to establish at the bureau. One-half of the tunnel connecting the two buildings described, is going to be set aside for our new bench standard.

*Mr. Warder*—In regard to molecular action in the metal bar, how much time should be allowed after the bar is rolled for the molecules to arrange themselves so that there shall not be a subsequent change in the bar?

*Prof. Stratton*—We propose to use a portable forge, or make some arrangement by which we can build an ordinary coke or charcoal fire and heat the bar in sections of about eight or ten feet and anneal it properly throughout its entire length, but before the holes are drilled for the plugs. After the bar is in place and the plugs put in at proper intervals, then the bureau will send a representative to put marks on the plugs and graduate the length in terms of the national standard. After a careful annealing you will never be troubled with any change in the bar.

*Mr. Geo. H. Bremner*—Should this bar be polished off in any way?

*Prof. Stratton*—No, a rough black bar is all that is necessary.

*Mr. Bremner*—Should there be any care taken about its being near electric wires or steam pipes?

*Prof. Stratton*—I do not think electrical wires could possibly have any effect. In the case of steam pipes, I think it would be better to keep the bar away from them. Of course, if the standard is a steel tape it does not make any difference.

*Mr. L. E. Cooley*—How far is the power of the United States exclusive in this matter of standards, and how far does the authority of the states extend?

*Prof. Stratton*—It is a national question with reference to the fundamental standards. That is, the questions of the fundamental standard of mass, length, and certain electrical standards, are all national questions. But the sub-divisions, or, I should say, the arbitrary units, are often matters of state law. For instance, the pound is fixed by the national government, but the state establishes the bushel or the barrel as based on the pound weight.

*Mr. L. E. Cooley*—In this adoption of the metric system by the United States, does that apply to the Land Department?

*Prof. Stratton*—I should have stated that all land surveys are excepted. I do not think there is a thing in the bill that would be objected to by anyone who desires to see a universal standard, and I do not see how anyone can believe that the metric system will not become the universal system, when the extent to which it is used to-day is considered. The manufacturers are rapidly coming round to this way of thinking. The National Tube Works has one of its largest mills fitted up for the metric system. The Carnegie people are getting out their handbook in the metric system. I recently sent out thirty or forty letters to different manufacturers to find out whether I could obtain machinery and supplies for equipping our shops for turning out work in the metric system, and in nearly every case I found that I could get all that was necessary. There is no use in making a greater problem of it than it is. Whether or not the manufacturer uses the metric system in constructing machines is of no consequence to the public, and it is merely a question of the economical working of his own shop. It seems to me the questions to ask are, can we get material in the metric dimensions? Can they get plates rolled to the metric system? Can they get tubes? They are getting them now; there is not a thing they cannot get in the metric system. The object in introducing it into government work is, that whatever extra expense is involved would be shared by the government. Yet we find some people who are still bringing up the old arguments of the interchange in systems, the great change in machines, templates, etc.

*Mr. J. W. Schaub*—The difficulty would be in the shop. They would convert this system into the common system before passing it into the shop.

*Prof. Stratton*—They do both. Sometimes it is more convenient to convert.

*Mr. Schaub*—I think it would be difficult to get men in the draughting room or shop who would be sufficiently familiar with the metric system to understand and *think* in that system.

*Prof. Stratton*—I do not think a man is competent to be in a draughting room who cannot take up and learn the metric system in a short time. In my experience I have never yet found a workman who did not take pride in being able to use the metric system.

*Mr. Schaub*—What we have to do under these circumstances is to convert all machine measurements into the common system, and put them into the shop that way.

*Mr. Hatch*—It seems to me that it would be easy for the workmen to learn the new system, and I think they could learn it in a very few days, if it were an object.

*Mr. Bley*—The most of the gentlemen who have spoken here tonight are those who have had experience in a scientific way, but the majority of measurements are not made by chemists and scientific men; it is probable that they make the most accurate measurements, but it is the carpenter, the blacksmith, etc., who do the most of ordinary measuring, and they are the ones, it seems to me, to be considered. If you have a scale divided into the binary system, it is easy to pick out the subdivisions. But take our binary system of a unit and divide it down to 64ths and then convert it into decimals, it would be very complicated. While I have that objection to the decimal system, I am in favor of the decimal system as against the varied systems we have. I think it is an advantage to have one system of weights and measures instead of more. I think it is desirable to have one system of measure of volume instead of several. I believe at the time I went to school we had about three different measures of volume, viz.: Wine measure, ale and beer measure and apothecaries' fluid measure. I also think that when a better than the decimal system is found, it will be easier to change from one single system to another one, rather than from many standards to one. Nevertheless, the decimal system is a nuisance in the actual measurement.

*Mr. W. L. Abbott*—I would like to call attention to the fact that civil engineers have taken their two-foot rules and rubbed out the inches and divided them into tenths and hundredths.

*Mr. Liljencrantz*—About fourteen or sixteen years ago, the question of adopting the metric system was taken up at sundry meetings of this society. There were then two factions—one in favor of the change and one opposed. Mr. S. S. Greeley was the principal spokesman for the adoption of the system and Mr. Latimer was strongly opposed to it. I was on Mr. Greeley's side, and came to the conviction of the desirability of this system by a train of reasoning. In the first place I considered it of the greatest importance to get a uniform system of weights and measures for this country. Then, with the constantly increasing interchange of commerce between nations, it certainly would be very important to have a system uniform for all civilized countries. The superiority of a "decimal" system as a universal one being beyond question, it would not seem reasonable to expect that countries having already adopted the metric system would be willing to abandon that for one based on the foot, or the yard, or the inch, and therefore I came to the conclusion that nothing but the metric system could give universal satisfaction.

Mr. Latimer admitted the advantage of a "decimal" system, and I presume that no engineer could be found who could do otherwise, but Mr. Latimer had some very peculiar reasons for his objections to the "metric" system. One reason was because of the inconsistency of having an arc for the unit for linear measurements. In theory that objection may be admitted, but I hardly think Mr. Latimer would have expected anyone to use that arc to test the accuracy of a certain measure.

The second reason that Mr. Latimer gave for his averse opinion was, I think, a little worse yet. He claimed that the English inch was given to us for a unit by the Lord, in the pyramids, and it would therefore be sacriligious to use any other.

I am glad to know that Mr. Greeley has again called up this subject. It will certainly be of great interest to hear from him, for he has collected a great deal of data, showing the confusion now existing in the various weights and measures in use in the different parts of the country.

Regarding the establishment of standards that are accurate and accessible, in each of the United States, that is something that I suppose could hardly furnish any occasion for discussion, for the advantages are so clear and self-evident that all that this society could do would be to unanimously and emphatically express its full appreciation of this important undertaking.

*Mr. Chas. W. E. Clarke*—In my experience I have found it an advantage to use the metric system. I used to lay it out in inches and transfer it into meters, but we found we had to go back to meters. I became used to the system in a very few weeks.

*Mr. L. E. Cooley*—I think we will all agree that the system is good for the other fellow and good for those who come after us, and as long as we are allowed to think in any system we please for our own personal use, I do not see how anybody can object to the change. Some of us old fogies will come to it gradually.

I think we are under many obligations to Prof. Stratton for his presence this evening and for his most interesting address.

*Prof. Stratton*—I should like very much to take back with me an opinion from this society, as you have no idea how much weight such an opinion would carry with those who have these matters in hand. Some of them feel that there is a difference between practical and scientific work, and whenever they receive an opinion from those who are engaged in practical work, it carries great weight in Washington.

# APPENDIX

## TREASURY DEPARTMENT.

CIRCULAR OF INFORMATION OF THE

## NATIONAL BUREAU OF STANDARDS, NO. 1.

### ANNOUNCEMENT OF ORGANIZATION

By an act of Congress approved March 3, 1901, the office of Standard Weights and Measures of the Treasury Department was, on July 1, 1901, superseded by the National Bureau of Standards, the functions of which are as follows: The custody of the standards; the comparison of the standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the government; the construction, when necessary, of standards, their multiples and subdivisions; the testing and calibration of standard measuring apparatus; the solution of problems which arise in connection with standards; the determination of physical constants and the properties of materials, when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere.

The Bureau is authorized to exercise its functions for the government of the United States, for any state or municipal government within the United States, or for any scientific society, educational institution, firm, corporation, or individual within the United States engaged in manufacturing or other pursuit requiring the use of standards or standard measuring instruments.

For all comparisons, calibrations, tests, or investigations, except those performed for the government of the United States or state governments, a reasonable fee will be charged. Provision is also made for the purchase of a site and the erection of a suitable laboratory, its equipment with the most improved facilities and the personnel necessary for the organization of the Bureau.

A suitable site has been selected in Washington in a locality free from mechanical and electrical disturbances, and yet easy of access. Plans are being prepared for a physical laboratory which will be equipped with apparatus and conveniences for carrying on investigations, and for testing standards and measuring instruments of all kinds. Also a somewhat smaller building, to be known as a mechanical laboratory, which will contain the power and general electrical machinery, the instrument shop, refrigerating plant, storage batteries, dynamos for experimental purposes, and laboratories for electrical measurements requiring heavy currents.

The construction of the buildings will be pushed as rapidly as possible, and it is expected that they will be ready for occupancy by January 1, 1903. For the present, additional quarters have been secured in the building occupied by the former Office of Standard Weights and Measures, with a view to the organization of the Bureau and the immediate development of the more needed extensions of the work heretofore carried on, such as photometric measurements, the testing of instruments for determining high or low temperatures, clinical thermometers, chemical glass measuring apparatus, electrical apparatus used to measure alternating currents, pressure gauges, and meteorological instruments.

For the present, however, the work of the Bureau will be limited to the comparison of the following standards and measuring instruments, either for commercial or scientific purposes:

Length Measures.—Standard bars from 1 to 10 feet, or from 1 decimeter to 5 meters; base bars; bench standards; leveling rods; graduated scales; engineers' and surveyors' metal tapes 1 to 300 feet, or from 1 to 100 meters.

Weights.—From 0.01 grain to 50 pounds, or from 0.1 milligram to 20 kilograms.

Capacity Measures.—From 1 fluid ounce to 5 gallons, or from from 1 milliliter to 10 liters.

Thermometers.—Between 32° and 120° Fahrenheit, or 0° to 50° centigrade.

Polariscopic Apparatus.—Scales of polariscopes, quartz control plates and other accessory apparatus.

Hydrometers.—Alcoholometers, salinometers, and saccharometers, whose scales correspond to densities between 0.85 and 1.20.

Resistances.—Standard coils of the following denominations: 1, 2, 5, 10, 100, 1,000, 10,000, 100,000 ohms; low-resistance standards for current measurements of the following denominations: 0.1, 0.01, 0.001, 0.0001 ohms. Coils of resistance boxes; potentiometers; ratio coils.

Standards of Electro-motive Force.—Clark and other standard cells.

Direct Current Measuring Apparatus.—Millivoltmeters and voltmeters up to 150 volts; ammeters up to 50 amperes.

It is the desire of the Bureau to cooperate with manufacturers, scientists, and others, in bringing about more satisfactory conditions relative to weights and measures in the broader meaning of the term, and to place at the disposal of those interested such information relative to these subjects as may be in possession of the Bureau. All communications and articles should be addressed "National Bureau of Standards, Washington, D. C."

S. W. STRATTON,
Director.

Washington, D. C., January 1, 1902.

# CL.

## THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

A Discussion.

*June 18, 1902.*

In view of the special attention given to the metric system of weights and measures in the paper read by Mr. S. W. Stratton, on May 7, the Board of Directors decided that a special meeting should be held for the discussion of the metric system, with its advantages and disadvantages. The following circular was therefore sent to all the members of the Society, announcing the purposes of the meeting:

June 10, 1902.

Dear Sir: —At a regular meeting of the Western Society of Engineers, held May 7, 1902, Prof. S. W. Stratton, Director of the National Bureau of Standards, Treasury Department, Washington, presented a valuable and interesting paper on "The Work of the Bureau of Standards," showing what was being done and what was projected. Incidentally a strong plea was made in favor of the Metric System of Weights and Measures, and he urged that this Society take some action toward endorsing the bill now before Congress, establishing the Metric System of Weights and Measures in the United States. There was some discussion of this subject among those present, following the paper of Prof. Stratton, and on motion, duly seconded, the Board of Direction was asked to consider the matter and in what way it should be handled to get the sense of the Western Society of Engineers, for or against the measure pending before Congress.

This subject has been duly considered by the Board of Direction and the conclusion was reached that a special meeting of the Western Society of Engineers be called for Wednesday evening, June 18, 1902, for a full discussion of the Metric System of Weights and Measures, and the desirability of its adoption by the United States. At this meeting it is desired to have a full attendance of the members of the Society, and invitations will also be extended to those engaged in manufacture and commerce, who would be in a position to add something to the discussion. After the discussion of this subject, the question whether or not the Western Society of Engineers should lend its influence in favor of the bill now before Congress remains to be settled, and for this purpose you will be asked to express yourself by means of a letter ballot.

You are respectfully asked to give this subject your consideration, and if possible be present at this meeting, June 18, to discuss the above question. If you cannot be present, please send in a written discussion.

By order of the President.

J. H. WARDER, Sec. W. S. E.

The bill before Congress is here presented.

57TH CONGRESS
1ST SESSION

# H. R. 123.

## IN THE HOUSE OF REPRESENTATIVES.

DECEMBER 2, 1901.

Mr. SHAFROTH introduced the following bill; which was referred to the Committee on Coinage, Weights, and Measures and ordered to be printed.

# A BILL

To adopt the weights and measures of the metric system as the standard weights and measures in the United States.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That on and after the first day of January, nineteen hundred and three,* all the Departments of the Government of the United States, in the transaction of all business requiring the use of weight and measurement, except in completing the survey of public lands, shall employ and use only the weights and measures of the metric system; and on and after the first day of January, nineteen hundred and four,* the weights and measures of the metric sytem shall be the legal standard weights and measures of and in the United States.

This bill was referred to the House Committee on Coinage, Weights and Measures. The report of this committee was submitted by Mr. Southard, and on April 21, 1902, the report was referred to the House calendar and ordered to be printed. The following is the text of this report (57th Congress, 1st. Session, House of Representatives, Report No. 1701):

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*These dates have since been changed to 1904 and 1907, respectively, as noted further on.

## REPORT.

The Committee on Coinage, Weights and Measures, to whom was referred the bill (H. R. 123) to adopt the weights and measures of the metric system as the standard weights and measures of the United States, having duly considered the same, respectfully report as follows:

By Section VIII of Article I of the Constitution power is vested in Congress to fix the standard of weights and measures, and yet, strange as it may appear, this is about the only great and important subject intrusted to its care by the express provisions of the Constitution which has been almost wholly neglected. Again and again has the necessity for a change in our system of weights and measures been urged upon the attention of Congress. Washington more than once pointed out the importance of securing a uniform system of weights and measures, and early in the history of our country the matter was referred to Jefferson, then Secretary of State, who proposed two plans, one an adaptation of the existing system and the other a strictly decimal system.

John Quincy Adams, as Secretary of State, after four years of careful study, made a report which is worthy of the attention of the most advanced thinkers upon this subject at the present day. He pointed out the failure of the English people to reduce to any sensible order the chaos of their weights and measures, and urged upon Congress the necessity for a reform. He, however, advised delay until the metric or international system, which was then in its infancy, had been more fully tried, and to which he referred in a most glowing tribute as possessing all of the requisites of a simple, uniform and workable system of weights and measures.

Since that time the adoption of the metric system has been repeatedly recommended by the departments of the Government and Congressional committees. The annual report of the Secretary of the Treasury for the year ending June 30, 1899, contains the following clear and concise statement:

> The intense commercial rivalry of nations warns us to leave nothing undone which might further our own interests, and there can be no doubt that the introduction of the metric system, to which this country stands pledged since the meeting of the International American Conference in 1890, would greatly facilitate international commercial transactions. Without doubt Great Britain and Russia would follow the initiative of this country in this matter, and thus, what a few decades ago would have been considered an unattainable ideal, namely, a system of weights and measures common at least to all western nations, would be reached.

It is not the purpose of this recommendation to place before Congress a full discussion of this subject. The various committees appointed by it from time to time to consider this matter have made exhaustive reports covering aspects of this question no less important than the commercial one—reports always agreeing on the necessity for reform, always considering our present system a temporary one and out of harmony with our decimal notation and monetary system, and since 1866 always recommending the introduction of the metric system.

The great difficulties which seemed to stand in the way appear to have been overrated, for its introduction into Germany, Austria and other European countries was accomplished with little or no confusion. This Government, therefore, would not enter upon an untried experiment if its obligatory introduction in all governmental affairs was ordained, as it has been in the countries named.

The subject of a reform of our system of weights and measures engaged the attention of Washington, Jefferson, Madison and Adams, and in Congress the reports of Messrs. John A. Kasson in 1866, Alexander H. Stephens in 1879, and Charles W. Stone in 1896 and 1898 advoçated the introduction of the metric system.

Among my predecessors, Robert J. Walker, in 1847, urged it upon Congress, Secretary Chase gave it his support, and Secretaries Windom and Foster successively concurred in the favorable recommendation of Secretary of State Blaine. Secretary Carlisle adopted as fundamental standards for the Treasury Department the metric standards prepared at the International Bureau of Weights and Measures, an establishment maintained by the principal nations of the world. The various States of the Union were, by the action of Congress in 1866, supplied with copies of the principal metric standards.

All these facts exhibit a consistent endeavor on the part of the executive, as well as the legislative branches of our Government, from its foundation to the present time, to reform our heterogeneous metrology.

As the present time seems most opportune and the matter of great importance it is recommended that Congress take such action as will bring about the desired end.

The delegates of the United States to the Pan-American Congress were instructed in 1889, by the Secretary of State, as follows:

(1) That the desirability of promoting the establishment of an international system of weights and measures be recognized as a principle of action in legislation.

(2) That the decimal or metric system shall serve as the basis of unification.

(3) That all nations, not already parties to the convention signed at Paris, May 20, 1875, establishing an International Bureau of Weights and Measures, shall become parties thereto.

(4) That the aggregate statistics of international commerce shall be, where it is not yet being done, published also in metric equivalents.

(5) That all invoices shall be made out in metric weights and measures where weights and measures appear, as far as they relate to the commerce between the nations participating in this congress, and that the table of equivalents herewith shall be recognized as legal by the nations taking part in this

congress, in converting the customary weights and measures of the United States into metric weights and measures in making such invoices.

(6) That metric weights be used exclusively in the mints.

These are but a few of the recommendations that have been made by the officers of the Government and others in authority from the beginning of the Republic to the present time. To these must be added the efforts of many of the best men of the country in all lines and professions, scientific societies, commercial and manufacturing organizations, who have striven to bring order out of chaos, and who have recognized the value and importance of a suitable system of weights and measures to every interest of the country. While these efforts have met with practically the unanimous approval of all who have given the subject any attention whatever, the failure of these efforts to bring about the adoption of a better system of weights and measures has been due to the willingness with which many would rather endure a present evil than submit to a temporary inconvenience for the benefit of the present and future generations.

### THE WEIGHTS AND MEASURES IN COMMON USE.

A complete list of the weights and measures in common use would be difficult to make, and would involve much space. The various units have been inherited from a time when exact measurements were unheard of, computations were seldom made, and when each locality and different interest had its own system of measures. Modifications and adjustments had been made from time to time; nevertheless, it is still full of inconsistent ratios, difficult to learn and still more difficult to remember. The units are not related to each other; many units of the same name have entirely different values. It is unsuitable for computation, and is not decimal in character. The advantages to be gained by the adoption of the metric system as compared with the one in present use are far greater than the benefits derived from the adoption of a decimal system of coinage in place of the English monetary system.

It is a popular fallacy that our weights and measures are in accord with those of Great Britain, but this is not true, as neither our pound, yard, gallon or bushel are identical with the corresponding English units.

Very few people are familiar with the weights and measures in common use in the United States. One has but to recall the tables of our three different systems of weight, the apothecary, troy and avoirdupois, to illustrate this fact. And while the yard may be stated as our standard of length, we find in practice various arbitrary multiples of the yard and foot; for example, the fathom, the surveyor's and engineer's chains and links, the nautical and statute miles, hands, poles, perches, and various others. In addition to the ordinary cubic measure, we find three systems of measuring capacity, dry measure, liquid measure and apothecary's fluid measure. To these might be added a large number of technical standards in use in the various trades and industries in common use which would be greatly simplified and unified upon the adoption of the international system of weights and measures. An examination of the tables of our weights and measures discloses the fact that there are 64 different ratios used, of which 19 are not divisible by 2, and that there are 18 terms used which have two or more meanings. Certainly any effort to replace this conglomerate system with a simple, logical one, similar to our monetary system, is worthy of the consideration of Congress.

## THE METRIC OR INTERNATIONAL SYSTEM.

The metric system of weights and measures was devised as an international system. The fact that it was first adopted by France has given rise to the custom of referring to it as the French system. It is interesting to note, however, that one of the first to propose a decimal system of weights and measures was James Watt, the inventor of the steam engine. The adoption of a decimal system of coinage by the United States was one of the strongest influences leading to the adoption of the metric system by France. The unit of length in the metric system is called the "meter," and was defined as the one ten-millionth part of the distance from the equator to the pole of the earth measured on a meridian. The first of these units to be constructed was by the French Government, and was based on the best known measurement of the earth's surface at that time.

An international congress was held in Paris in 1875 for the purpose of improving the standards. Accordingly, a number of meters were constructed of the best material and by the best methods known to science. One of these was selected as the international standard of length, and is very carefully preserved at the international bureau of weights and measures established and maintained by the countries participating in the congress and those which have joined the convention since. These meters were very carefully compared with the one selected as the international standard, and then distributed to the countries interested. The unit of mass or weight, as it is commonly called, is the "kilogram," and is defined as the mass of a cubic decimeter of pure water at a standard temperature. The international committee also prepared forty pieces of metal equal in mass to that of the cubic decimeter of water, alike in form and of the same material as the standard meter, the most permanent metal known. One of these was retained at the International Bureau of Weights and Measures as the international kilogram.

The same precautions were observed in the comparisons with each other and with the one selected as the international standard before distributing them to the respective governments. Of the two meters and two kilograms sent to the United States one of each is preserved as the national standard of length and mass. The others are taken as working standards, and serve as the basis of all comparisons of length or mass in this country. The fact that the meter is only approximately a natural standard as originally intended has sometimes been used as an objection to the metric system. This, however, is of little importance, since the meter and the kilogram as constructed are as permanent as it is possible to make material standards, and are far more accurate than any measurements that can be made of the earth's surface. If at any time a suitable natural standard should be discovered, the meter would simply be defined in terms of that standard as it originally was in terms of the earth's quadrant.

The advantages of the metric system may be briefly stated as its decimal character throughout, the simple relations between the units making it possible to derive all others directly from the unit of length, its elasticity (being equally convenient for the measurement of the smallest or largest objects), the ease with which it is learned and remembered, the saving of time, and the increased accuracy with which computations may be made. These advantages have been proven by a century of use, but that which especially commends it to us at the present time is its international character, since it is the opinion of all who are in a position to know that the world must soon come to an international system of weights and measures, and that there is not the slightest possibility of our own system or any modification of it becoming universal.

## THE METRIC SYSTEM AS USED IN SCIENTIFIC WORK.

Scientific investigators early recognized in the metric system of weights and measures a simple, flexible system equally suitable for the most refined or coarsest measurements, or for purposes of computation. As a result the scientific world to-day enjoys the advantages of a universal system of weights and measures, a fact which has greatly facilitated the development and spread of scientific knowledge. The practical applications of scientific work have in many cases been seriously handicapped or retarded owing to the necessity of converting formulæ derived in the metric system to equivalent formulæ in the common system. If the formulæ and other data used in manufacturing and engineering were universally expressed in the metric system, it would greatly promote the growth and dissemination of such knowledge throughout the entire world.

### BENEFITS TO BE DERIVED BY EDUCATIONAL INTERESTS.

The benefits to be derived from the adoption of the metric system by the educational interests of the country are perhaps the most important that have been brought to the attention of this committee. Estimates made by the Department of Education and others show that the work of at least two-thirds of a year in the life of every child would be saved by the adoption of the metric arithmetic. The British Parliamentary committee having in charge a similar investigation estimated the saving of time at one year. This is a matter the importance of which can hardly be overestimated, taking into consideration the large amount of work to be covered in the curriculum of the schools and the enormous sums annually devoted to educational work. The metric system is taught in nearly every school in the country. Teachers and pupils alike unanimously testify as to the ease with which the system is taught and learned and the facility with which it is applied to the problems which in ordinary arithmetic are complex and difficult to solve. When we consider that there are over 15,000,000 school children in the United States being educated at a public cost of not less than $200,000,000 per year, the enormity of the waste will be appreciated. In the lifetime of a single generation nearly $1,000,000,000 and 40,000,000 school years are consumed in teaching a system which is in harmony with that of no other nation of the world.

In higher education the metric system of weights and measures is used almost exclusively, and attention is called to the action of the associated academic principals of the State of New York—a body of some 700 high school principals, superintendents, and prominent educators—which has passed the following resolution in regard to the adoption of the metric system:

> *Resolved*, That we hereby instruct our legislative committee to forward to Congress of the United States, if there shall be suitable occasion and opportunity, our earnest petition for the enactment of such legislation as shall render the use of the metric system obligatory throughout the United States.

Many similar actions by educational bodies of all kinds throughout the country have been called to our attention.

It is a matter of evidence on the part of educators in the United States, Great Britain, and Continental Europe that the metric system and its application to the solution of problems may be learned n one-tenth the time required for gaining an equal facility in the use of the English system of weights and measures. It is doubtful whether any measure of more vital importance and benefit to the educational interests of the country has ever come before Congress.

### RELATIONS TO MANUFACTURING INTERESTS.

It should be emphasized that this measure in no way contemplates any change in existing technical standards, such as screw threads, wire gauges, lumber measures, and numerous others, except as manufacturers and other interests involved find it to their interest to make the change. Doubtless a change in the fundamental standards of length and mass would facilitate the simplification of such standards; but the changes would still be brought about as heretofore by the special interests involved.

Any change in the standards employed in manufacturing, no matter how perfect the system proposed or how beneficial the change may be, must be very carefully and judiciously made. In the case of textile fabrics, materials of construction, package goods, and almost all kinds of manufactured products, a change would no doubt involve some inconvenience, but the expense of modifying existing plants or machinery would be very slight. In many cases no change or expense would be necessary, and the benefits to be derived from a convenient and universal standard would far more than compensate for the expense and confusion temporarily involved during the transition stage.

The relation between the manufacture and the sale of these products is so close that any change in the system of weights and measures which will lessen the burden and expense of the counting-room and office is worth the cost, considered from the standpoint of economy alone. The action of many associations of manufacturers and merchants, both in the United States and Great Britain, has been called to our attention, and without exception they have urged the adoption of the metric system of weights and measures, on account of its international character and superiority over the present system for manufacturing and commercial purposes.

In no other country has the construction of machinery reached a degree of perfection superior to that of our own, a result principally due to the system of interchangeable parts. The latter may be said to be a product of American ingenuity and to be the greatest single advance in modern machinery. It has for its essential features a uniform standard of length and accurate length-measuring instruments. This work has been done upon the basis of the inch, which in many cases has been decimalized.

There are a few who claim that the inch is better suited for this purpose than the units of the metric system. However, it should be kept in mind that the interchangeable system does not depend upon the unit used, but upon uniform, reliable standards and accurate measurements, and it is difficult to see why the inch and fractions of an inch should be superior to the centimeter and decimals of a centimeter. German, French, English, and American manufacturers are successfully manufacturing upon a metric basis and have shown no desire to return to the old system, notwithstanding the fact that the change has been made in the latter cases under very adverse circumstances.

It is admitted that the temporary inconvenience caused in the shop and drafting room by the proposed change would be very serious if suddenly brought about, but any measure which contemplates only the gradual introduction of the one system for the other, or even the continuation of the old by all except the departments of the Government in case it is desired, can not be said to be compulsory or capable of producing more than a minimum of inconvenience or expense, and certainly an interchangeable system upon an international basis will be superior to one based on the standard of a single country.

### THE NECESSITY FOR THE METRIC SYSTEM IN COMMERCE.

The enormous development of the commerce of the United States within recent years has brought to the attention of our merchants and business men the great advantages to be derived from the adoption of an international system of weights and measures. The use of the old system not only involves great loss of time in making computations, but places our merchants at a great disadvantage in dealing with countries which have already adopted the international system.

More than 60 per cent of our commerce is now carried on with countries using the weights and measures of the metric system, and it is evident that the commerce of the world must soon conform to the metric basis.

Theodore C. Search, president of the National Manufacturers' Association of the United States, states as follows:

> Wherever manufacturers undertake to extend their trade in foreign countries, they encounter the metric system, and it is the only system of absolute uniformity which prevails throughout the world. The pound, the quart, the gallon, the ton, have varying values, wherever encountered in foreign countries, and to insure accuracy the use of those units requires further explanation and some qualifying description in order to indicate just what quantity is meant. The enormous growth of our export trade during the past four years has brought our manufacturers in touch with the outer world as never before, and has given very practical illustration of the cumbersome character of our methods of measurement, and the

advantages to be derived from the adoption of a system which is absolute and uniform throughout the world. * * *

And as we have only just entered upon a commercial conquest of the world, utility of the metric system will become more and more apparent and the necessity for its adoption more urgent with each year of our growing export trade. The extension of our governmental functions to the Philippines, Cuba, and Porto Rico brings into the circle of our commercial operations millions of people to whom the metric system is the recognized standard and to whom our own cumbersome system of weights and measures are a strange and unknown language of trade.

We recognize that any effort to supplant our present system of weights and measures with the metric system will be attended with more or less difficulty, and will involve some trouble for many of our manufacturers, because of the necessity of changing drawings, patterns, and standards, but we believe it entirely possible to accomplish such a change by gradual steps, and there should be no necessity for causing loss or injury to any of our industrial interests.

It seems to me that every argument is in favor of the unification of standards of weights and measurements throughout the world, and for us to insist upon an adherance to our antiquated standards is not in accord with the progressive nature of our people and the progressive tendency of this age.

Mr. W. O. Wilson, director of the Philadelphia Commercial Museum, states as his belief that "millions of dollars are lost every year in transposing our weights, measures, and money from that of one country to another in our international business relations."

The testimony of Mr. Godfrey L. Cabot, a prominent merchant of Boston, includes the following statement:

Wherever this great improvement has gone, it has simplified the ordinary commercial transactions of daily life, minimized disputes, and given an absolute standard from which there could be no appeal and in which there was the least possible danger of error or misunderstanding.

### RELATION OF THE METRIC SYSTEM TO TRADE.

The necessity for an improvement in the weights and measures of the country is nowhere more apparent than in the ordinary business transactions of daily life. Grain and produce are bought and sold by capacity measure, the bushel, peck, and quart. The necessity for handling these commodities in large quantities by weight has resulted in the adoption of different weights for a bushel for the same commodity in different parts of the union, and in a few of the Western States the hundredweight is used instead of the bushel. The diversity in this respect is so great that a correct table of the number of pounds to the bushel of different commodities for the several States is difficult to procure.

The long, short, and gross tons, without any distinction in name, are used in the buying, selling, and transportation of coal, ore, metals, and other heavy products. For liquids in large quantity the barrel used has many different values, and we find in common use often side by side avoirdupois weights, troy weights, apothecary weights, and the weights of the metric system. To add to this confusion the subdivision of the ordinary measures are often not adhered to. The engineer uses the foot and tenths of a foot instead of feet and inches; the manufacturer, inches and decimals of an inch instead of adhering to the binary division; the gauger uses gallons and tenths of a gallon. In the handling of bullion we find troy ounces and thousandths of an ounce instead of ounces and grains. The engineer has discarded the inch, while some manufacturers of machinery have discarded the foot, hence we find tenths of a foot and the inch in common use. These are but a few of the instances where the introduction of the metric system would not only afford the advantages of a decimal system but furnish a system sufficiently elastic for all purposes. The experience of other nations has shown that the confusion and inconvenience caused by a change in the measures used in daily life was largely overestimated, and in no case have the people expressed a desire to return to the former system of weights and measures.

## CONCLUSION.

The countless transactions involving the use of weights and measures makes any proposition involving a change a most important one. The decimalization of our system of weights and measures has been proposed by a few who have failed to consider the importance of an international system and the utter impossibility of the rest of the world adopting such a system as our own, however it may be improved in form. A change of this sort would be incomparably more radical than the adoption of the metric system. It has also been proposed to modify the existing system to one having a base of eight or twelve on account of the possibility of continued binary subdivision, but here again not only is the importance of an international system overlooked, but the impracticable idea is proposed of combining such a system with a decimal system of numbers. When the base of our system of numbers is changed to some other than ten it will be sufficient time to talk about a system of weights and measures having the same base.

It should also be kept in mind that the metric system is just as capable of a binary subdivision as any other, although the advantages of such a division are only apparent in the most ordinary business transactions, and for the first few subdivisions. After the adoption of the metric system, the use of the half and quarter meter and a half and quarter kilogram would be as common as our half and quarter dollar—smaller quantities would be expressed in decimals precisely the same as in the case of our money.

In 1866 Congress legalized the metric system. From that time on it has been growing in favor and in practical use. It is here to stay, not only in scientific work, but in commerce and manufacturing. It is now used by about two-thirds of the people of the world. Russia, Great Britain, and the United States are the only nonmetric countries. Russia has gone so far in the direction of its adoption that it may well be excluded from the list, leaving Great Britain and the United States. In both of these it has been legal for some time. Indications are that Great Britain will soon join the list of metric countries. Over 300 members of Parliament have already signified their willingness to vote to make the use of the metric system compulsory.

Your committee believe the time has come for the gradual retirement of our confusing, illogical, irrational system and the substitution of something better. The first step in this direction should be the introduction of the metric weights and measures into the Departments of the Government. The use of these weights and measures will simplify their work. It will familiarize the people with them and encourage their application to the common affairs of life. Your committee have no doubt that the benefits to be derived will far more than compensate for such inconvenience and expense as may be involved in the change.

Your committee have amended said House bill 123 in line 4 by striking out the word "three" and inserting in lieu thereof the word "four;" also in line 9 by striking out the word "four" and inserting the word "seven."

As thus amended your committee earnestly recommend the passage of the bill.

## APPENDIX.

### REPORT OF THE SELECT COMMITTEE OF THE HOUSE OF COMMONS ON WEIGHTS AND MEASURES APPOINTED TO INQUIRE WHETHER ANY AND WHAT CHANGES IN THE PRESENT SYSTEM OF WEIGHTS AND MEASURES SHOULD BE ADOPTED.

They have in the first place received evidence from witnesses representing many different interests, (1) official, (2) commercial, (3) manufacturing, (4) trade, (5) educational, (6) professional.

They have also received from numerous corporations, school boards, and other public bodies resolutions without exception in favor of the adoption of the metrical system.

Your committee find that almost all the witnesses express a strong opinion as to the complicated and unsatisfactory condition of our present weights and measures, and of the distinct and serious drawback to our commerce, especially onr foreign trade, which this system entails, differing as it does from the system (metrical) now adopted by every European nation except ourselves and Russia, as well as by far the majority of non-European countries with which this Kingdom trades. The evidence, however, goes further to show that not only is our foreign trade in every branch seriously handicapped, but that the home trade would be benefited if more simple and uniform standards of weights and measures than those now existing were adopted.

Moreover, strong evidence was brought forward as to the serious loss of time incurred by English school children in having to learn the complicated system of tables of existing weights and measures, and the urgent need of the adoption of a simpler system. It was stated that no less than one year's school time would be saved if the metrical system were taught in place of that now in use.

Evidence from competent witnesses proved to the satisfaction of your committee that a compulsory change from an old and complicated system to the metrical had taken place in Germany, Norway and Sweden, Switzerland, Italy, and many other European countries without serious opposition or inconvenience. That this change was carried out in a comparatively short period, and that as soon as the simple character of the new system was understood it was appreciated by all classes of the population, and no attempt to use the old units or to return to the old system was made.

In the United States, where a system founded on the English units exists, a commission is at present engaged in an investigation of the same character as that with which your committee is charged.

Your committee believes that the adoption of the metrical system by England would greatly tend to render that system universal.

Your committee recommend :

(a) That the metrical system of weights and measures be at once legalized for all purposes.

(b) That after a lapse of two years the metrical system be rendered compulsory by act of Parliament.

(c) That the metrical system of weights and measures be taught in all public elementary schools as a necessary and integral part of arithmetic, and that decimals be introduced at an earlier period of the school curriculum than is the case at present.

## PROCEEDINGS OF THE SPECIAL MEETING.

The special meeting (No. 475) of the Western Society of Engineers, called for June 18th, was duly held, with President Finley in the Chair.

*Mr. Finley*—The question of the adoption of the metric system of weights and measures by the United States has been brought before other societies, and we thought it best to call a special meeting of this society for the discussion of the subject, and if possible crystalize an opinion either for or against it.

As I understand, it is desired that the Society shall go upon record for or against the bill now before the House of Representatives making the adoption of the metric system compulsory by a certain time.

The Secretary then read the following letters sent in, in response to the circular of June 10th, 1902:

*Arch. R. Eldridge, C., B. & Q. R. R., Chicago* — It is, perhaps, presumptuous for one who is not a member of the Western Society of Engineers to enter into one of its regular discussions, but the importance of the subject in question will be the apology of the writer for so doing. The desirability or non-desirability of the adoption in the United States of the metric system of weights and measures has been discussed time and again so long as the writer can remember, and it is his belief that its adoption is a trifle nearer than it was a decade ago. The system has much to recommend it, and the writer has never heard advanced against it any argument other than it would cause great confusion because it would have to be learned, not only by engineers and others of higher education, but by all mechanics and artisans as well, and these latter have been using the present system for so many years that they would take up the new with difficulty. Let us take up the question one side at a time, beginning with the advantages, and let it be stated right here that there are very few engineers in this country who know less about the metric system, as applied to practice in every day work, than does the writer. In the abstract, the metric system has everything in its favor, and all for one reason—it is a decimal system. Where would our calculations be today were it not for the partial decimal system which we use? The old surveyor's chain, 66 feet in length, was divided into 100 links in order that the decimal system might be employed in calculating areas. Its very length, an odd one at first glance, was so fixed because ten square chains made one acre—the decimal system again. This old chain, convenient though it was, has been practically supplanted by the "engineer's" chain, with its decimal division into 100 feet. In all calculations, be they for bridge work, sewers, water-works, or what not, we reduce all of our figures to feet and decimals thereof, and then, when we have finished our calculations, which have been greatly facilitated by the transformation, we turn around and reduce our results back into feet, twelfths of feet, and halves, quarters, eighths, sixteenths or thirty-seconds of twelfths of feet. Rather a curious and useless proceeding for such progressive men as American engineers are supposed to be. In addition to this, it is well known that when we want to express a result exactly we are forced to use either decimals of a foot or of an inch, as our clumsy system of measures does not permit the use of a fraction of an inch other than the half, quarter, eighth, sixteenth, thirty-second or sixty-fourth. We could express a measurement in, say fifteenths of an inch, but you can readily imagine how such a proceeding would be received by an engineer or a workman. In regard to the disadvantages of the metric system, no argument can be advanced except that it would have to be learned. Of course it would; everything we know had to be learned, and it is safe to say that learning the metric system would be about the easiest piece of useful knowledge that any of us ever acquired. All can go back in memory to early arithmetic days, days when we had just begun the study of decimal fractions. How we hated them. How hard we thought they were. How we would surreptitiously work the example by means of common fractions because it seemed so much easier than awful decimals, with the decimal point which would never be found in its right place. Those were trying days for a while, but they did not last long, and it was but a short while before we arose and called decimals blessed, and began to tremble with horror whenever we saw the "old-fashioned" fraction put in an appearance. It is much the same now; we fear to take up the metric system; we fear that it would be hard to learn, and yet we admit that it is the easiest system in which to work, and in proof of this we use decimals so far as our system will admit. In weights it is the same. We have partly discarded the old "long ton" of 2,240 pounds and adopted the ton of 2,000 pounds, an approach towards the decimal, and we generally express our weights or strains in tons and tenths, hundredths and thousandths of a ton, the loved, yet feared, decimal coming in again. As to the laborer, the mechanic, he would have less trouble than any of us: He would have his measure divided off into metric distances, and all he would have to do would be to lay it upon his work and mark off what his plans called for. For a time there might possibly be some inconvenience, as a distance expressed in meters would not convey anything to one as the distance expressed in feet would, but this would soon wear off, and the awkward and clumsy "foot" would be speedily and gladly forgotten. As regards metric weights, the same arguments apply to them as to measures. Our system of weights is as clumsy as is our system of measures, and both need revising badly. It is generally conceded that the metric system would be a vast improvement upon the one which we now use, and the only reason advanced against it is that it would be rather hard for us to get into the habit of using it. If such be the case, is it not rather cowardly of us to shirk it? Are we not retarding progress rather than facilitating it, and is not the retardation of progress diametrically opposed to the mission of the engineer?

*Chas. H. Tutton, M. W. S. E., Buffalo, N. Y.* Replying to your circular letter of the 10th, relative to the metric system, I would state that I cannot be present on the 18th inst. The same subject is to be brought up shortly before our local society here-the Engineers' Society of Western New York. So far as I have talked with the engineers here, I have yet to find a single one who is in favor of its becoming the national standard. I am decidedly not in favor of it as an individual. I have found it cumbrous and unwieldy in transformations necessary to adapt to English formulæ and measures, and in practice its units are either too large or too small, requiring subdivisions which I understand is done in France itself to thirds and quarters. It is unscientific and inaccurate, not being as near to the supposed portion of the arc of the meridian as the English inch is to a decimal division of the earth's polar axis, and its standard is consequently a certain metal bar in Paris.

Finally, I should oppose it for the following, if for no other reason, which you can consider as bigoted or prejudiced if you like, but as our national life is due to the influences of Christianity, and civilization is measured directly by that standard, I do not call it by quite so harsh a name.

The metric system was born as a reaction against, or rather hatred of religion. It was the offspring of an attempt at anarchy and ruination of progress. It originated in passion and the attempt to root out everything good. It stands today as a protest against everything good, and is abhorred in nature. It is associated with such names as Danton and Robespierre not directly, maybe, but inferentially. Even as it is the remaining infernal mark made against humanity, so would I consign it when it attempted to consign life, liberty and justice.

The above is scarcely written as a discussion of the subject, being disconnected and wandering. Have been interrupted about ten times while writing it, which accounts for it. I see by a document issued by the Government that they claim it has been endorsed by the American Society of Civil Engineers. Several of the members inform me that that statement is untrue, and I think, were it put to vote, that it would be overwhelmingly defeated.

*Oscar Sanne, M. W. S. E., Brooklyn, N. Y.* It was a great pleasure for me when I received the communication from your Secretary, dated June 10th, regarding the desirability of the adoption of the metric system of weights and measures by the United States.

There is no question in my mind that it is not only desirable but necessary for the United States to adopt the metric system; necessary surely for a greater and better development of our international technical relations.

When I came to this country, about twenty years ago, I felt the difficulty of adjusting my German technical education to the weights and measures of this country. Today it is just the reverse, because I now have pretty hard work to see at a glance the meaning of kilograms and centimeters, when comparing German and French construction with our structural work. This, of course, is only one of the many points which would favor a radical change to the metric system.

Anyone familiar with the drudgery in a drawing-room of a bridge company or machine shop will agree with me that it appears to be a waste of time and money to space everything in feet, inches and fractions of an inch. The metric system simplifies and affords an easy and quick manner to overcome all fractional difficulties.

During my stay with the Edge Moor Iron Works, about nineteen years ago, I had occasion to hear some strong arguments against the metric system, but I thought then that such arguments were very short-sighted. The difficulty which presents itself to the manufacturers will be paid many fold by a more accurate and quicker work of the shop men after they have been thoroughly and properly trained, and have been provided with all the necessary information to compare the old with the new system.

I remember, when a boy of about thirteen years of age, that the metric system was introduced in Germany, but with such an iron consistency and energy that it took hardly six months to make the new system the property of the nation.

In conclusion, let me say that I have not the least doubt that, with the clearness and practical sense of the American people, this system will, if properly taught in all schools, all shops and all households, soon be ours, and a blessing to this wonderful country.

*F. B. Macomber, Assoc. M. W. S. E., Chicago*—Referring to your circular letter of the 10th inst., which I have given consideration, would say, inasmuch as it will be impossible for me to attend the meeting called for on the 18th inst., I take this opportunity of advising you that personally I am in favor of a metric system of weights and measures in the United States, and feel that this should have the support of our Society and other organizations of the same character, and be carried to a finality through Congress, establishing the metric system in the United States.

*E. French, M. W. S. E., Detroit, Mich.*—Replying to your circular letter regarding the adoption of the metrical system of weights and measures in the United States, I have to say that this system should have been put in force years ago, and no doubt would have been had it not been for the prejudice against any innovation displacing a system which was so thoroughly established in the minds of the people as our present system of weights and measures. There is just as much reason in the adoption of the metrical system of weights and measures now as there was for our forefathers in the establishment of the United States currency, discarding the English system and adopting a system based upon the decimal idea.

*W. F. Mann, City Engr., Kokomo, Ind.* In answer to your circular letter to the members of the W. S. E. pertaining to the desirability of bringing the Society's influence on Congress to pass the pending bill to establish the metric system of weights and measures throughout the United States, I desire to say that I am heartily in favor of doing whatever can be done to bring about the adoption of the system of said weights and measures. Our system of weights and measures are interminably mixed, complicated, and often of an uncertain meaning. Long and sometimes useless tables are required in our linear measurements, and a great amount of labor is required in transferring one measurement into another. Time and patience are consumed in reaching accurate and reliable results, and all on account of the several kinds of units used. These can all be fused and run into one—the meter. It is definite, clear and precise in its meaning, and can be made sufficiently exact for all practical purposes. The quicker rods, perches, poles, feet, inches, links and yards are eliminated from our text-books the better. The same is true of the units of capacity and weights. They are fully as badly tangled as the linear units, and nothing whatever is gained by retaining and teaching them. They are useless and antiquated rubbish, and require three times as much labor to master them as would the metric system. The metric system is bound to become the universal one, and is now among the scientists, and the quicker we fall in line the better it will be for us. We, as a nation, can little afford to lag in this matter, a very important one, and I should favor any measure that would carry along the good work.

*F. Sargent, M. W. S. E., Chicago*—Replying to your communication of the 10th inst., I beg to state that it may be impossible for me to attend the meeting on the 18th inst., and discuss the subject of establishing the metric system of weights and measures in the United States. I therefore desire to state that I am not familiar with the bill now before Congress referred to in your letter, but on general principles I am in favor of the adoption of the metric system of weights and measures in the United States, and would favor any effort in that direction.

*H. P. Boardman, M. W. S. E., Milwaukee*—Not being familiar with the text of the bill before Congress, I cannot well discuss that, but as to the adoption of the metric system for general use, I think it is a step in advance of present methods in this country and that it is pretty sure to come sometime. It is, in fact, gradually coming into use now, and is very largely used in many technical and other scientific institutions. It will be impossible to make everybody *think* weights and measures in the metric system at once, so there will be a transition period, and a long one, during which it will be necessary for people of many vocations to be familiar with both systems, and able to readily reduce from one to the other.

I am told that in Germany, after the metric system had been in use for years, merchants still kept scales and measures of the old system so that, to satisfy some customers, they could and often did sell by the pound or yard, although if caught by government inspectors with old scales or measures in their possession they were very likely liable to fine.

Such a radical change would affect, not only engineers, but practically every human being in the country, and of necessity would cost an immense sum of money. Engineers, always more or less familiar with arithmetical calculations, should more readily adapt themselves to such new standards than most others, and I think few engineers will dispute a statement that the metric system is in itself better than our present mixture of systems and units.

In a few years after such a change, and in some cases immediately after, much engineering work could be done with no reference to former units, but in many kinds of engineering and surveying work a familiarity with old systems will have to be maintained indefinitely. I think that when once it has come into general use, and when all who cannot understand or appreciate it have passed away, the metric system will save much labor and time, and possibly enough to pay financially for the great expense of the change. If it is desirable at any time, then now is the time to adopt it, so let us favor it for the good of posterity, if none of the other arguments for it appeal to us.

The Secretary also read a communication from Mr. S. C. Stickney, General Manager of the Chicago Great Western Railway Co., St. Paul, as follows: "Please record me as voting against any changes in standards of Weights and Measures."

The following letters have been received, but were not presented at the meeting of June 18th:

*A. Bement, M. W. S. E., Chicago*—Being unable to attend the meeting of June 18th, I would say that my understanding of the provisions of the bill now pending before Congress is, that it is intended to make the metric system the legal standard for government work, but does not in any other way make the use of the system compulsory. I think that this measure should have the endorsement of the Society, because the tendency would be to promote the gradual extension of the use of this method.

The accompany report of the testimony of Mr. John A. Brashear before the House committee, as given by the *Iron Age*, presents the matter, I think, very clearly:

Mr. Brashear, who was the next witness, said that he had been interested in the subject of metrology since a boy; but that when he first began to work upon the subject practically he was prejudiced in favor of the old English system, because he had learned his trade on that basis. "But it was not very long after I got into the business of making astronomical and astrophysical instruments," said he, "that I found the orders I was receiving came largely from foreign nations, and I found myself forced to begin to study the metric system. There was at the outset a spirit of rebellion among the workmen, as well as myself, but we finally had to get down to it, and when I had new lathes constructed I had them all made with the metric screw thread. About ten years ago Dr. Mendenhall, who was superintendent of the Coast and Geodetic Survey, delivered a lecture before the Engineers' Society of Pittsburgh, of which I happened to be president, in regard to the use of the metric system, which had such an influence upon the engineers and upon myself that we decided at once that all papers and drawings submitted to our society should have weights and measures expressed not only in the English system, but also in the metric. Soon after that I ordered metric rules and gauges for my own shop, and installed the complete metric system of measurements, with all the tables and with computations on blue prints, so that my men can take up any measurements in the English system and turn them at once into the French system. For the past ten years we have been working very largely on the metric system in our workshops, although I regret to say that we now receive orders from the United States Naval Observatory in the English measures, while from the Smithsonian and the Coast Survey they come in metric measures, and we must satisfy both of them.

"I wish to say emphatically that the workmen find it easier to work in the metric system, which they find so simple because of the logical transition from the meter to the decimeter and the centimeter and the millimeter, etc. Our orders come from all over the world, including Russia, Asia Minor, Norway, Sweden, Germany, France, Spain, Italy, Switzerland and South America, in the metric system. All these nations use it, and I can see no way of stopping the wheels of this Juggernaut; if we do not get from under it we will be crushed."

In reply to an inquiry, Mr. Brashear stated that the measurements received by him from Russian customers had been in the metric system for the past twenty years, although the Russian Government had not yet formally adopted the system. The only orders received in the English system came from the United States and from England and her colonies, including Canada. A member of the committee inquired whether the witness employed metric screw threads, to which he replied in the affirmative, stating that no difficulty whatever was encountered in changing from any standard of screw threads to the metric. Continuing, Mr. Brashear stated that he had recently received an order for an instrument which required a precision of one and one-half millionths of an inch, and that in reaching such accuracy it was necessary to employ light waves for purposes of measurement. He was frequently surprised to note the accuracy with which young men employed in his workshops but a single year would be able to work a metal or glass surface, some of them working as close as 1 10,000 mm. In reply to a question, Mr. Brashear said he thought if the United States adopted the metric system England would be compelled to do so. When asked whether it would be beneficial to the export trade of the United States if the metric system should be adopted by this country, Mr. Brashear said

"I think the benefit could hardly be calculated. It seems to me it would be enormous."

*O. Chanute, Past President W. S. E.*—There has lately been a great change in the views of civil engineers concerning the adoption of the metric system, and I believe that a majority are now in favor of making it the standard.

I remember very well that when its adoption was first seriously promoted thirty years ago, the general opinion among leading engineers was that it was inexpedient and undesirable to adopt it for the United States. Its people were then engaged in the task of developing the continent, and the principal markets were at home, while our chief foreign commerce was with Great Britain. Now our manufacturers produce a large surplus, and look to outlets in foreign countries using the metric system. Many engineers have had occasion to become familiar with it, and have recognized its advantages.

Meanwhile this system, originating in France about a century ago, has become international, and has been adopted in thirty-six countries, including Belgium, Germany, Austria, Sweden, Norway, Holland, Switzerland, Italy, Spain, Bulgaria, some countries in Asia and Africa, all of South America and Mexico. It is stated to be in use by 448,000,000 of people, and that it will soon be adopted in Russia and Denmark, while it seems almost certain that Great Britain will also change over within a few years.

It has always been felt that the change should be made in this country at about the same time as in the British Empire, as this remains the nation with which we have the largest trade and relations. Great Britain has been investigating the subject through a select committee of the House of Commons, which has reported favorably, and some 259 members of Parliament have pledged themselves to vote for the change to the metrical system. If the time at which this shall go into effect can be determined by international agreement, it will be well; if not, the present House Bill No. 123 should, in my judgment, become a law.

There doubtless will be considerable expense, loss and inconvenience at first. Although many of our people have during this generation been gradually educated to the metric system by the exigencies of their business, there remains the great mass to be informed, but all the testimony from other nations seems to show that this is surprisingly easy when once the system becomes obligatory.

The chief objections come from the makers of machinery, and their principal argument is that it will disturb our very satisfactory system of screw threads and of interchangeable parts, which has grown up during the last thirty years. These are rational and weighty objections, yet they should give way to the national good. Moreover, interchangeable parts will continue to be made upon the old system as well as upon the new, and it has been suggested that the present screw threads may be retained in connection with the metric system, in which there is as yet no standard of screw threads, by the simple expedient of distinguishing the various pitches from each other by the letters of the alphabet instead of the awkward fractional parts of the meter. Be this as it may, I believe that the difficulties will be found much less than expected, and that we may have a surprise similar to that attending the resumption of specie payments, when the reform went into effect on the day fixed, without the slightest hardship.

Probably more force will be required in shops and offices during the transition period, but less afterwards. I believe, myself, that the metric system may fairly be inaugurated in the general government business in 1904 or 1905, and be made obligatory upon the whole people in 1907 or 1910 without serious difficulty. It is not possible to estimate the cost of making the change. This may run up to $100,000,000, although it is difficult to see how, unless the temporary inconvenience be included. If, after it is established, the metric system profits an average of one dollar a year to each of our population, it is seen that the return will be a high percentage.

## DISCUSSION.

*E. E. R. Tratman, M. W. S. E., Chicago*—In talking over this matter with engineers, I have found that there is a very vague idea, as a rule, concerning the actual terms or purport of the bill now pending, and which this Society is asked to endorse. I am very glad, therefore, that the bill has been read before the meeting and will be printed with the report of the proceedings.

It should be made clear in the discussion that it is not the metric system which is primarily under consideration, nor is it the advisability of the introduction of this system. It is the question as to whether the government should undertake to hasten its introduction by making its use compulsory in the government departments, which means its compulsory use also by manufacturers and others having business relations with these departments.

It will be seen that the bill is so worded that, on the face of it, its provisions apparently apply only to the departments of the government. This seems at first sight to make it of limited scope, and this has, in fact, been urged by some advocates of the bill to silence opposition by showing that the bill is, after all, quite harmless and might as well be passed. But in a very clear statement made to the House Committee on Coinage, Weights and Measures, in February last, Admiral Melville, who is one of the leading lights of the engineering profession, showed that this would require all work done under government contracts (as well as that done in government shops) to conform to the metric standards. All specifications would have to be prepared on the metric system, bids based thereon, and work done according to metric dimensions. Such a practice would, in many cases, restrict competition to those who were prepared to supply or manufacture materials under the metric system, and such restriction or discrimination would seem to be unwise and entirely unnecessary. Admiral Melville, in his statement, explained that 90 per cent. of the work done by the government is done by outside parties, and all this work would necessarily be included in the metric system, should this bill be passed.

In reply to the Admiral's statements, showing the complications and difficulties which the new system would involve in shop and machine work, it has been explained that the change would involve only the measuring instruments, gauges, templets, reamers, taps and dies, drills, etc. But the work done by the shops is of much greater importance than the mere change in the machines themselves. All dimensions of all kinds of manufactures would have to be expressed in the new system, and here the advocates of the bill are entirely at a loss. Shall the actual dimensions be changed to fit the nearest metrical measurement, or shall the dimensions be retained but expressed in metrical measurements? The former would require new patterns and a more or less complete change in the dimensions of a machine. The latter would involve only a relettering of the drawings, but would result in a bastard or compromise measurement, with somewhat minute fractional figures.

In either of these changes, the difficulties in repair and renewal work would be enormous, and would be more serious than those of manufacture. An example is that of a dredge boat built for use on some western or southern river, far away from industrial centers. For repair work, reliance must be placed on local machine shops, blacksmith shops and hardware dealers, and either the ordinary standard bolts, nuts, pipe, wire, fittings, etc., must be used, or else every piece must be made to order at some distant shops that are fitted for work on the metric system. The former method would probably be followed, but to comply with the law the engineer would have to write his orders or requisitions in metric measures. Thus, for a piece of 2-inch pipe, he would order a piece of 5.08 centimeter pipe, and would probably have to send a mechanic with each order to explain to the storekeeper or the local shop foreman or dealer what the requisition meant. In guns and ammunition the complication would be most serious, and would almost certainly involve difficulty in making or supplying the proper ammunition for the various kinds and sizes of guns.

The two methods of converting ordinary to metric measurements for dimensions of individual parts have already been referred to, and the advocates of the bill have taken no position on this point, and seem to think that either method can be followed indiscriminately. But for fine measurements it will readily be seen that a dimension of inches and fractions expressed in the nearest metrical figures will be very different from a dimension made to an exact metrical measure. As an example of how little the advocates of the bill appreciate the practical difficulties and problems involved, it may be noted that Mr. Stratton, Chief of the Bureau of Standards, made the following remarks before the Congressional committee: "I take it that this legislation does not involve the introduction of metric screw threads. This is a matter that should be left to the manufacturers for decision." But there is nothing in the bill that exempts screw threads, and if all parts of a machine must be made to metric measures with the exception of screw threads, then questions of measurement will be hopelessly involved. Even if legislation on this subject is in general advisable, it should certainly not be enacted until the difficulties involved have been dealt with in a much more definite way than they have been at present.

There is another point. Legal compulsion must include a penalty for disobedience of the law, if it is to be of any effect, but the bill does not provide any penalty, nor does it seem possible that a penalty could be devised or enforced. In litigation before the United States courts this bill cannot make legal papers invalid if they should give measurements or dimensions in any but metric figures. The only penalty would be that enforced in an indirect manner by government discrimination against those who do not use the metric system, and such discrimination would be both unwise and unfair. In fact, it is questionable whether in government contract work the lowest responsible bid could legally be rejected simply because the bidder did not employ metric figures.

The use of the metric system was made legal by Congress several years ago, and many of the government bureaus engaged in scientific work have already adopted it. Many manufacturers are also employing it, and government bureaus, engineers and manufacturers may use and adopt the system whenever they consider that it will be of advantage to do so. No further legislation is needed, therefore, to legalize the metric system, but the object of the present bill is to compel the use of this system, the compulsion being more or less indirect or concealed, as already explained.

The objections to the bill are not so much in regard to the introduction of the metric system as of the compulsory introduction of this system under the bill. As the system is already legal and is already in extensive use, while its use is extending, as freely acknowledged both by advocates and opponents of the bill, it does not appear that any further legislation on the subject is required. Certainly not legislation of a compulsory character, as devised by the present bill. Nor does it appear that such compulsion is necessary or called for, or that the bill would confer any advantage upon the people. On the contrary, it appears very unwise for the government to undertake or attempt to force upon the people the use of any particular system of weights and measures, even if it would confer benefits or advantages far in excess of those claimed by the advocates of the bill.

The government has already made the use of the metric system legal, and beyond that point the government should not go. Without presenting any objections against the metric system itself, I would enter a protest against legislation whose purport or effect would be to make its use compulsory.

*Mr. Liljencrantz*—As I was unavoidably late in arriving, I heard only the latter part of Mr. Tratman's remarks, and therefore it may be a little unfair to express myself. Still, from what I did hear of the paper, I infer that Mr. Tratman is opposed to the compulsory adoption of the metric system by the government. In my opinion I think the only way to make satisfactory progress in this country is to have a compulsory adoption of this system within a reasonable time. What that reasonable time should be I would not undertake to say now.

When we compare all the details of the complicated systems now in vogue with the simple metric system, it seems impossible to me that anybody can consider the latter in any other way than decidedly favorably. We all know that great reforms of any kind create confusion and inconvenience for a time, and a great many people—particularly those who have been accustomed to the various systems are averse to a change and desire to keep on with the measures to which they have been accustomed. That is natural. If a certain system is acknowledged as a great and important improvement on one that has been used heretofore, then I think we would all agree that it should be generally adopted, but if it is left to individuals to adopt a new system as they may see fit, it will take a very long time before it will become universal. Everyone, I think, will admit the importance of having a decimal system instead of the various systems we now have that are very irregular. It will also be admitted, I think, by everyone that if a universal system can be adopted that is universal, not only for this country but other countries with which we have dealings commercially and otherwise, it will be of great advantage.

The metric system has already been adopted in a large number of civilized countries, and it would hardly be fair to expect those countries to abandon that system for one equally good, being also a decimal system based on a different unit; as for example, if in this country the decimal system with the foot as a unit should be adopted. Perhaps I have not expressed myself clearly, but I mean that a decimal system, if based on the foot as a unit, would be equally good as a decimal system,and would be satisfactory in that respect, but when a decimal system is already adopted in other countries based on the meter as a unit, you could not, in order to get a universal system for all countries, expect them to abandon their established system for one based on the foot as a unit. Therefore, I consider the metric system as of greatest advantage, and that its adoption should be made compulsory, for, as stated above, if it is left to individuals to adopt it gradually as they see fit, it would take too long a time to accomplish the reform.

*Mr. Finley*—Mr. Tratman, in that part of his remarks referring to calling for bids, states that competition would be restricted to those who were prepared to supply or manufacture materials under the metric system, if that system were to be adopted, and mentions the chances of bids being thrown out if the bidders were not conversant with the metric system. I will say that at a meeting of the Committee on Weights and Measures a number of manufacturers and scientists were heard, and among them was Mr. Westinghouse. He says:

" If you wish to make it effective, the government ought to give 1 or 2 per cent. more for machines made in the metric system. That would be a compulsion that would be very effective. It is a question of self-interest in these matters, and this prejudice that I referred to is so strong, with old people especially."

Of course, understanding his position in the commercial world as a large manufacturer, his opinion carried considerable weight.

He was asked by the Chairman of the Committee if they were correct in their understanding that he was opposed to the metric system, to which he replied:

" On the contrary, if America is looking forward to capturing the commerce of the world, many of its products will have to be made according to the French measurements. For instance, in France they require everything to be made according to the metric system."

Mr. Westinghouse was then asked if he thought that ultimately one system would prevail. He said:

"It seems to me that it should. I think that is self-evident. It is only a question of the manner of requiring it that is involved. It seems to me that you can accomplish more by gentle pressure than any swiftness with which you may proceed. There is the real difficulty. Every man in the United States is so very busy making things, and they are making them according to drawings on the old system. Now, it is not going to be convenient in a day, or a week, or a year even, to change all those drawings. The system once decided upon, the new designs could be done according to the new system, and finally we would work over to it."

*Mr. Liljencrantz*—Mr. Chairman, that includes just what I tried to explain, although I have not the power to express myself as briefly and to the point as in the remarks read.

*Mr. Tratman*—Mr. Westinghouse shows very clearly in his statement, and statements by other manufacturers show the same opinion, that the metric system is already being quite extensively used in this country. Now, I believe, in opposition to Mr. Liljencrantz, that it would be a great deal less trouble and more beneficial generally to spread this introductory period over a number of years. It is developing in all kinds and lines of trades, and in scientific work and instruments, and I think it would be much better to allow a natural development of the system than for the government to take a hand in the matter and enforce it. I do not think that is the duty of the government.

*Mr. Liljencrantz*—I think Mr. Tratman misunderstood me. I did not say that I thought it was the proper thing for the government to enforce the metric system in a short space of time. A certain number of years—say five or ten from now—should be allowed to accomplish the change, but I think there should be a fixed time, after which the metric system should be made compulsory, and that it should be the only accepted system to be used.

*Mr. B. B. Carter*—Regarding this point of the adoption of the metric system and the purchase of supplies, I do not think the point is well taken. It is a very easy matter and a matter of not as much labor as it appears on the face of it to transpose our present system of dimensions into the decimal or metric system. I say this from experience.

In a shop on the West Side which had a set of expensive gauges by the old system of inches, divided into fractions down to 64ths, they commenced the manufacture of a foreign design of machine in which the dimensions were expressed in the metric system. New drawings were made and the metric system was entirely adopted. The objection has been raised that if we transposed our present inches and fractions down to 64ths into millimeters, it would make a long string of figures. It is a fact that in this machine that was foreignly designed those figures were expressed with as many as five places of decimals, which was really expressing them in millimeters. In the last ten years or so it has been quite customary, in a great many shops for the finer class of work, to use the decimal system. Micrometers are divided into thousandths, and they often read to five ten-thousandths of an inch.

It seems to me that this opposition to the compulsory adoption of a standard system is simply a question of conservatism, and as a class these conservatives are opposed to all advancement. It seems to me that this is not the attitude of the American engineer. He is not wedded to any system that is in conflict with his own individual investigation and calculation, and for that reason I think it is very important that the engineers of the United States, who have shown by the way in which they have captured the trade in foreign countries that they are advancing, should be in favor of any system that is going to further advancement.

In regard to the government compelling the use of the metric system: It now compels a system. The government says that the standard yard is a standard measurement. That is a compulsory system. The government would not any more compel a meter than it would compel what it does now—the standard yard. The government simply says that is the standard on which things shall be sold. The compulsion is simply legalizing the metric system. They simply compel the abandonment of the old system, which in my opinion is a very important thing to do.

In regard to the changing of the taps and dies of standard threads, that is not at all serious. They can be made just as they are now, and you will find that in about ten to twenty years new designs will be made in which they will bring the standard down to a smaller number of decimal figures to express it. As soon as this is legalized or compelled, the supply houses making these standard tools will very quickly adopt it and will make a 1¼ inch tap the size marked 31.8 mm. or 32 mm., which will be practically the same, though not exactly correct.

*Mr. Trumbull*—It seems to me that this is a question of the "survival of the fittest."

In reading the different journals today, one is impressed with the number of societies that are aiming to adopt standards in all branches of business. This is not a question of civil engineering, or mechanical engineering, or any one branch. As our country has advanced, old standards have been superseded by those which are more modern, more universal. The rod and the chain are examples, having been weeded out as being superfluous, while the foot as a unit was extended in its usefulness to cover land surveys. The examples in the field of mechanical engineering are numerous, such as the standardization of screw threads, bolt head and nut dimensions, etc. Standard sections of rails, standard car couplings, standard conventional signs, are all in the same line of progress. Every national or international convention of scientific or engineering societies inaugurates some new standard of design or nomenclature.

All sections and all peoples are coming into closer touch. Hence the need of universal means of communication. Every hour cut off the running time between Chicago and New York, between Chicago and SanFrancisco; every hour cut from the sailing time across the oceans, is significant, and brings the question of the adoption of universal standards nearer to us for progressive action.

If, in the field of "Weights and Dimensions," the metric system is the "fittest," it will certainly "survive."

The scientific and engineering societies may voice the will of the professions, but it remains unquestionably for the United States government, after careful investigation of the situation, after seeking profound insight into the drift of what is best for the greatest number, not only to voice the spirit of progress but to direct knowledge into the proper channel, and to insure by proper legislation, that the progressive step may be effective.

*Mr. Liljencrantz*—When I was making my last remarks I had not read the writing on the blackboard, and I notice there that the change has been fixed for 1903–4. I must admit that I consider that entirely too short a time.

*Mr. Finley*—The time for general use in the United States is 1907. (See the Bill as printed on a previous page.)

*Mr. Milligan*—I would like to put myself on record as being in favor of the metric system.

There has been a gradual tendency toward the metric system; ever since I can remember it has been taught in public schools, and I think I am safe in saying, every technical school teaches it and urges its adoption, paying but very slight attention to the old system. I understand that engineers have practically adopted the decimal system, using the foot, or inch, as a standard. No doubt that would answer all the requirements of the metric system, so far as the need of the engineer is concerned, but they overlook one point and that is, in the metric system, there is a direct relation, and a simple relation, between linear measurement and those of weight and capacity. Each year the engineer becomes aware of the fact that the other sciences are getting more and more interwoven with chemistry. Probably there are few engineers that do not come more and more in business relations with chemists, and chemical engineers have adopted the metric system exclusively.

I should feel very sorry indeed, if so progressive a body as this Society of Engineers, should offer any obstacle to the adoption of a purely scientific system of measurement. I think that the point offered in the amendment is well taken. No doubt it will cause a great deal of confusion for a very radical change of this sort to be enforced at once, but in the natural order of things I think this Society would do well to urge the adoption of the amendment. I do not know that I am familiar with the term of years offered by the amendment, and I do not know whether I am satisfied as to whether that term is sufficient or not, but I think that if a sufficient term of years was interpolated as an amendment, and the attention of all the scientists was drawn to the fact, it would do away with any possible argument on the part of our friends, the conservatives.

As a young man I am heartily in favor of the adoption of the metric system, and I think the sooner we get it, the better.

*Mr. W. H. Pratt, North Works, Illinois Steel Co.*—I can only consider this question from the standpoint of the works I have charge of. I feel that the difficulty we would have in adopting the metric system, independent of its adoption by others, would be that we could not connect with our customers. If we should adopt it, or any individual should adopt it, it would be seriously embarrassing, for the reason that those making comparison might not use the same standard. For that reason I think it is imperative that there should be a law enforcing it. If each manufacturer was compelled to use the metric system, the time required to learn it would not be a long one, and every machinist or mechanic would be perfectly at home with it in a short time. The micrometers are all graduated decimally, and we first make our measurements with the decimal system and then reduce them to inches and fractions of an inch. I am not only in favor of the bill, but I would not favor a very large number of years for rounding up on it.

The convenience in making working drawings in structural steel work would be great. The fractions of inches which we use are frequently sources of error and causes of additional labor. The metric or any decimal system would be much simpler and more readily handled, enabling the men to turn out their work more rapidly and to a greater degree of accuracy.

*Mr. Warder*—In regard to your own line of work,—if we should adopt the metric system, all structural shapes instead of now being given in inches or fractions of an inch. and weight per foot or yard, would necessarily be furnished according to the metric system. That would necessitate a change in the rolls. What would it amount to? How often would you have to get out new rolls made according to new drawings?

*Mr. Pratt*—I do not think the adoption of the metric system would have anything to do with the sizes used. We could use our present sizes with less trouble with a decimal system than we could with the present system. I do do not think the introduction of the metric system would change the size of screw threads. It would only change the numeration which represents the size. We now, in taking the sectional area invariably use the decimal system in all our tables. When we compare the size of the nut with the size of the screw we use the decimal. The differences or clearances between parts which have to fit together are almost invariably a decimal part of an inch. It is more convenient.

*Mr. Warder*—What is the expense incident among the manufacturers in changing finishing rolls to bring them to these dimensions?

*Mr. Pratt*—The difference is so slight now that a slight change would make no difference with our system of using them.

*Mr. Carter*—Assuming the ordinary average roll, how often are they dressed?

*Mr. Pratt*—A roll will run probably a week or ten days, but sometimes not so long.

*Mr. Liljencrantz*—I think it is very clear that the greatest trouble in changing from one system to another will, as a matter of course, be during the transition period, while both systems are still in use, and if the change is not compulsory that period will be very much extended. That is one reason why I think the compulsory adoption of the metric system, if that is accepted as more favorable, should be made.

*Mr. Carter*—Just one more remark in regard to this question of compulsory adoption. The thought occurred to me that some several years ago the government took upon itself to say that the railroads should, within a certain time, adopt a standard coupling. During the transition period there was some confusion and trouble, but it came about and it has not caused any very severe expense or any great trouble.

*Mr. Liljencrantz*—If you will go out in the country today you will still hear some of the farmers speak of a certain distance as a rod. The compulsory adoption does not mean that one shall not express himself in any way he wishes. This is simply to be an official standard.

*Mr. H. B. Boardman*—About five or six years ago I was talking with Mr. Whitney, and asked him what he thought of the metric system. He said they used it then in their shop, practically; that it was not the metric but the decimal system. I asked him if he thought a change could be made, and he said he would be very glad to have it made; that they could take it up very quickly if others would only use it. He also said at that time that if the government would pass some measure making it necessary for everyone to use it, their shop would be among the first to adopt it. He thought it would be very desirable to make it compulsory and have a definite time set for its adoption.

*Mr. W. K. Means*—I wonder whether this bill, if it is passed in its present form, will produce any definite effect at the date set, except in an educational way. We have had governmental action suggesting pretty strongly that the metric system was coming, for twenty-five or thirty years, and it seems to me that now something in peremptory shape will wake up the parties to be affected by the change to a little more serious consideration of it and get them ready for it, and will be a good thing. But we may expect that when the date comes, Congress will yield to pressure and lengthen the period for the change a little, however long it now is made.

*Mr. Liljencrantz*—Mr. Means' remarks endorse practically what I said. If it is left for the people to make the change gradually as they please, it will take perhaps a half century before it is done. This is another reason why it should be compulsory.

*Mr. W. C. Armstrong*—I think the ground has been pretty well covered. I might say this, however, that if this matter is left to develop itself we may in time grow into the use of a decimal system, but it would not be the metric system. Now, I think that as the people the world over are becoming more homogeneous, as it were, we should aim to develop or adopt a system that would be universally used, and for that reason I think it should be the metric system. It seems to me that the bill is a good one from the fact that it will bring pressure to bear upon the development of the use of the metric system. If we leave it to grow just as it would naturally, it may be a hundred years or more before we would develop a perfect decimal system, but if we have some pressure from legislation it would not take long to do away with all of our difficulties and objections and establish it firmly.

*Mr. Carter*—Was there anything brought out by the Committee as to the number of countries and what countries have adopted the metric system?

*Mr. Finley*—I think so.

The Secretary here quoted from the Report of the Committee on the bill, as follows:

"In 1886 Congress legalized the metric system. From that time on it has been growing in favor and practical use. It is here to stay, not only in scientific work, but in commerce and manufacturing. It is now used by about two-thirds of the world. Russia, Great Britain and the United States are the only non-metric countries. Russia has gone so far in the direction of its adoption that it may well be excluded from the list, leaving Great Britain and the United States. In both of these it has been legal for some time. Indications are that Great Britain will soon join the list of metric countries. Over 300 members of Parliament have already signified their willingness to vote to make the use of the metric system compulsory.

*Mr. Finley*—Lord Kelvin says: "With England and America adopting the French metrical system, it will be practically a universal system."

*Mr. Liljencrantz*—I want to say this,—that if it is acknowledged as desirable to adopt the metric system, why delay it any longer than is necessary? Why not accept it as soon as it is practicable to do so?

*Mr. Tratman*—I understood from what Mr. Warder read that Great Britain is one of the three principal countries outside of the metric system. Should not that include all the British colonies? I do not know how it is in Australia, India and Africa. It seems to me none of those countries use the metric system.

*Mr. Milligan*—As I happened to be born in one of the English colonies, I would like to say that the metric system is taught in the common schools of Canada and its adoption has been urged by all the scientific bodies, and in the higher schools of education it is taghht almost exclusively. Canada struggles between three systems, the American, English and Metric, so that the confusion there is, so far as weights and measures are concerned, if anything, worse than in the United States, and I think that engineers and all scientific men in Canada would be well pleased if the metric system were adopted.

*Mr. Pratt*—I believe that it will be found that the people who would feel that there was a hardship forced upon them would be in the hopeless minority, and that the law would not be regarded by the majority as a compulsion of something that was antagonistic to the interests of anyone, but would be regarded more as an agreement of the people that it should be passed. If the people do not feel that way the law would undoubtedly be repealed before the date of enforcement.

*Mr. Finley*—There is no question but that prejudice and personal feeling have a great deal to do with the matter.

*Mr. John Brunner*—I only wish to say that I am most heartily in favor of the metric system and I believe the only way to get it generally used is to make it compulsory—that is, within a reasonable time—and I believe the amended bill gives all the time necessary to get it introduced.

*Mr. S. S. Van Der Vaart*—I do not believe I care to add very much, as the hour is late and the subject has been well presented, but I would like to ask if those who state that Germany adopted the system in six months are conversant with the facts. As I remember the matter, Germany threshed over the matter for five to ten years and the metric system had been gradually encroaching from France into Germany before the time was set when the use of it was to be made compulsory. I question very much whether in this country the setting of two or three years would result as favorably as the six months did in Germany. There is too much of a complicated mass. Our people are not as scientific as the Germans.

The papers I represent are papers that have a great deal to do with the export trade, and the export, also, of machinery, and I was speaking not long ago with one of the exporters, who said that many of the orders for parts are stated in millimeters and meters instead of in inches—the measures that are used in this country—and that he always has to get someone to translate the dimensions, which sometimes causes a great deal of trouble, because the fractional parts are not so easily translated.

I very firmly believe that compulsion is the only way of bringing about the change. I think that Premier Seddon, of New Zealand, has abundantly demonstrated in his country that compulsion means progress. Compulsion is only meant for our benefit. We are not compelled to do things that are not right, or are not, as this matter is, for our benefit. I believe that when the bill comes up there will undoubtedly be a movement for an amendment extending the time. I think I speak for the exporters in a great many lines, that the time be set at not less than five, and probably more than five years.

## RESULT OF LETTER BALLOT.

*August 22, 1902.*

The above paper on "The Metric System" has been sent out to 421 qualified voters, with a letter ballot, by which these voters were to record their wishes, whether or not the Society should endorse the Congressional bill to establish the Metric System of Weights and Measures in the United States. Replies have been received from 153 members, of which 130 were in the affirmative and 23 were in the negative.

J. H WARDER, Secretary. W. H. FINLEY, President.

Trafford Park.

# CLI.

## THE AMERICAN ENGINEER IN ENGLAND.

By Wm. G. Sloan, M. W. S. E.

*Presented May 28, 1902.*

For some time past the expression, "Americanizing England" has been commonly used, not only here in America but in England as well, to designate any departure from her present methods of doing work and transacting business and tending toward more expedient ones.

This from an American point of view, at least, must be considered complimentary to America and Americans.

During the past eighteen months I have had an exceptionally good opportunity to study English life and especially business life, and the methods of carrying on engineering work there. While the work, itself, with which I was connected does not afford material for a technically engineering paper, being only ordinary manufacturing plant construction, still it was exceptional in its magnitude, and I hope I may be able to bring to your attention some interesting facts growing out of, and in connection with this work.

On the western edge of Manchester, and not over five miles from its center, there is a large tract of land, the estate of the De Trafford family, baronets. Until four years ago, it had been the property of this same family, since the time of the Danes, and it was in every way typical of the estates of the English nobility. Near the center of this park was a fine old manor house, part of which was built over six hundred years ago. The house was approached by drives, lined on either side by shade trees and shrubbery so as to be almost hidden from sight when approached from some directions; behind the house was the conservatory and still farther back were the extensive stables. A part of the park was maintained as a game preserve, a thick growth of underbrush,—bracken and hazel, making it almost impossible to walk through it, and with the first attempt to do so, one would hear the whirr of the startled partridge, or pheasant, or see the form of a hare or rabbit disappear in the bushes. I might continue this description, if time would permit, but think I have said enough to give you an idea of what Trafford park was but a few years ago.

Ceremony of Laying the Corner Stone.

When the Manchester ship canal was built, it was so located as to run through the property, for a considerable distance, and the Bridgewater canal also forms the boundary of the estate on one side. It is also quite near several lines of railroad running into Manchester. These facts—i. e. good transportation facilities, and proximity to Manchester, made this a most valuable piece of ground for manufacturing purposes, and so when it came to pass out of the hands of those who had been its owners for so many centuries, it was purchased by a company who developed it into a manufacturing district.

This, then, is what we found at Trafford park; a district supporting manufacturing industries of many kinds, served by branch lines from the railways and canals; the old manor house being used as a golf club house, and the stables as a horse mart.

When the British Westinghouse Elec. & Mfg. Co. decided to build their plant they located it on the banks of the Bridgewater canal, in Trafford park.

The plant as designed and constructed, is in many respects similar to the Westinghouse Elec. & Mfg. Co.'s plant at East Pittsburg, Pa., with the addition of a steel foundry and an iron foundry.

There are other plants in the world as large and even larger than this, but without exception, I think, they are the result of growth-additions being made to the original buildings as became necessary. In the case of the plant under consideration, however, the condition was different, and I think I am safe in saying, it is the largest manufacturing plant ever constructed all at the same time.

The plant was built for the manufacture of Westinghouse electrical machinery and appliances and gas engines. But a casual glance at the conditions in England alone, to say nothing of the Continental countries, so far as electric street railways are concerned, would seem to show that the financial success of even so large a plant as this, is already assured.

It is amazing how slow England has been in the adoption of electric street railways, even in Manchester, a city of over a million inhabitants, where there was not an electric line until about a year ago, and to-day a large percentage of their street railways are horse car lines.

The plant was designed by Mr. Thos. Rodd of Pittsburg, and the work of construction was intrusted to a Manchester architect, but under his supervision the work progressed so slowly that it was evident to those interested something must be done to hasten the work. It was generally conceded by English builders that it would take five years to erect the works contemplated, and now, when the proposed output of the plant was most in demand, a delay of a year

Main Shop Under Constructon.

or two years meant an almost inestimable loss. The question was, how can the plant be completed in the shortest possible time? The Americans interested in the business naturally looked to America for an answer to this question, and the contracting firm of James Stewart & Company of St. Louis and Pittsburg, were asked to take hold of the work and push it through. This they agreed to do, saying, they could complete the work in fifteen months.

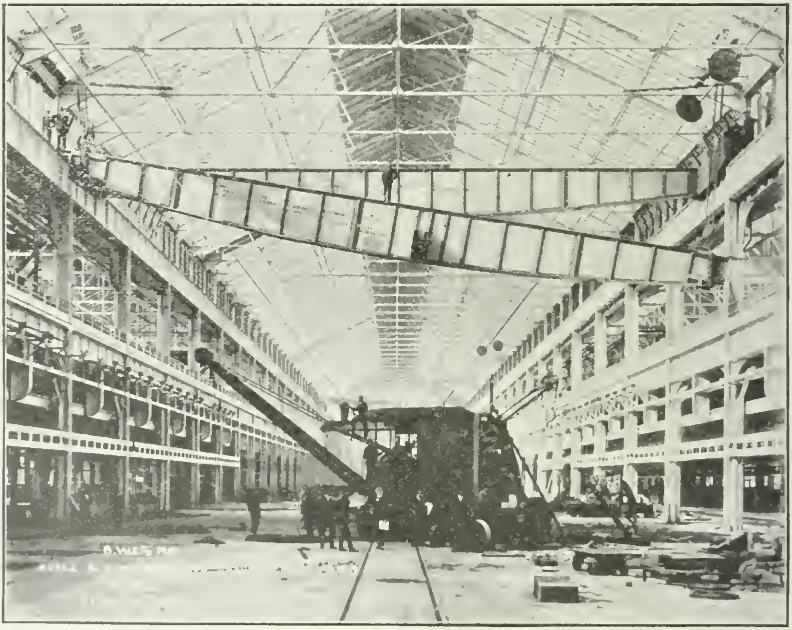
Therefore, a year ago last March, Mr. J. C. Stewart, of the above firm, having gathered around him a party of six American engineers and foremen, of which party I was fortunate enough to be a member, sailed for England, and on arriving there took immediate charge of the work.

It was evident at a glance that a complete reorganization was necessary, in the making of which we naturally met with considerable opposition, but Mr. Stewart was determined in his purpose to do the work, as far as possible, by American methods, and not many weeks passed before we had things running to our satisfaction.

We found the work in charge (under an architect) of a clerk of works, who had a small office in one part of the grounds. This man had perhaps a dozen assistants, each having his little office in some part of the grounds, each seemingly as far as possible from the others. The first thing done was to build an office large enough to accommodate all the necessary force, so as to bring them under the immediate supervision and influence of the American management.

All these men had been in the habit of coming on the work at nine o'clock in the morning, and leaving about five in the afternoon; they were requested to be on hand when the work started and to remain until quitting time, and this request caused about half of them to seek employment elsewhere, one of them saying in his letter of resignation, "A man cannot be a gentleman and work under the American administration." It may be of interest to state in this connection, that the average rate of pay of these clerks and inspectors did not exceed fifty dollars per month.

One custom we had the most difficulty in breaking down, was the old established one of stopping for the breakfast hour. The men started work at seven o'clock in the morning and at half past eight the work stopped for half an hour for the men to eat their breakfast; this consisted of bread and tea, and each man brought



Erecting a Traveling Crane in the Main Shop.

his tea and teapot with him to the work, and as I say, right in the best part of the morning, they all stopped work, and gathering in groups of three or four in a place, built little fires on the ground, heated the water and made their tea. You can readily understand, when you consider that at times we had as many as 3,000 men at work, how serious an objection this break in morning work would be; the men losing not only the half hour, between 8:30 and 9, but also wasting considerable time in stopping work and getting started again. We helped matters to a great extent by building a furnace and having the water hot for the men; making it a rule that no other fires should be lighted on the grounds. At the same time we discouraged in every way possible the keeping up of the custom, and finally, one by one, the different trades acquiesced to our wishes in the matter, and before the work was done, all but the bricklayers had given up the custom.

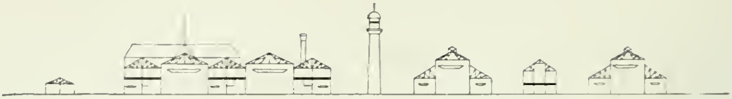
Now, as to the work itself: The buildings were built of steel with brick enclosing walls; the roofs were of slate and sky-light (50 per cent of the total roof area of the buildings was sky-light, this unusually large proportion being necessitated by the dark, gloomy weather of Manchester), the cornices, gutters, ventilators, and all exposed sheet metal work was copper; the foundations of all the buildings were of concrete, the nature of the soil (which was clay) making it necessary to carry the footings down about ten feet.

Where the foundation walls or piers carried steel columns, cap stones were used on top of the concrete. The English architect had allowed the top of these stones to be left rough, the stone being set sufficiently low, to allow the steel work to be wedged up about three-quarters of an inch, and the space between the stone and the shoe of the column grouted full of cement mortar. All the buildings were connected with each other and with the boiler house by tunnels, to carry the steam piping and electric wires. These tunnels were five feet wide and six feet high; they were built with concrete walls and roofed over with brick arches.

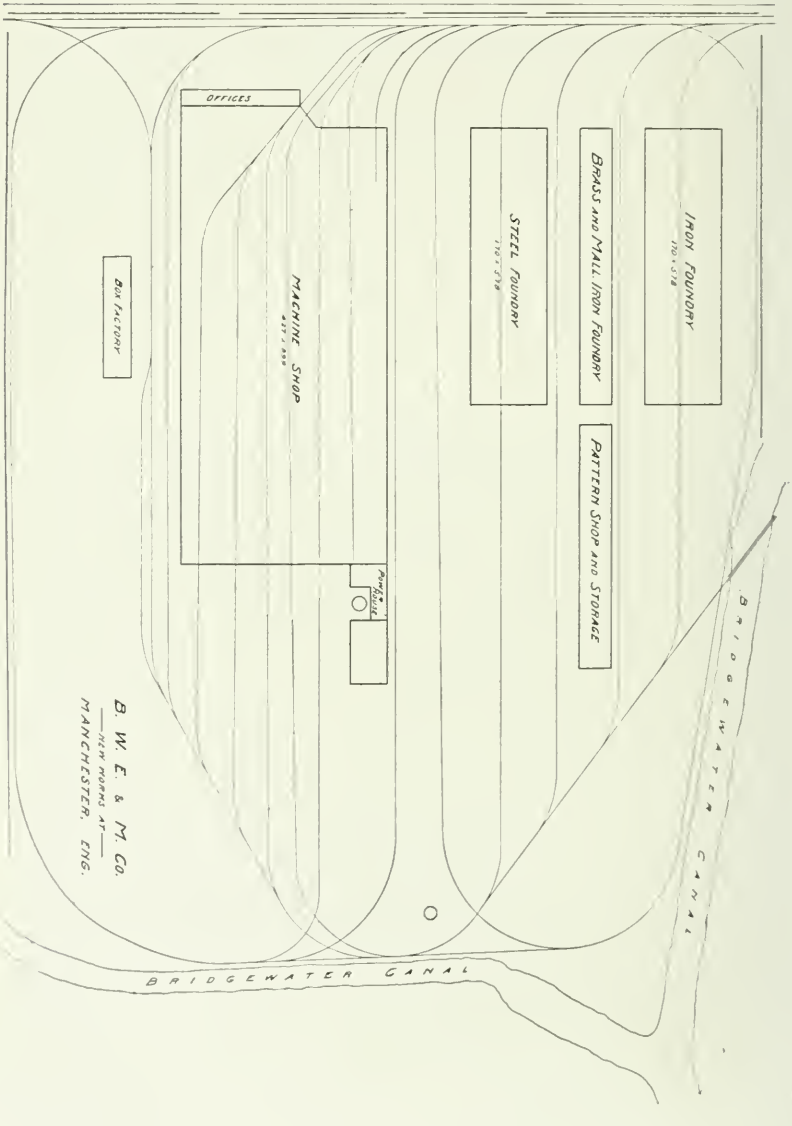
There were five large buildings and several smaller ones, also a six-story office building. All were fitted with Grinnel sprinklers as fire protection. There was used on the work 14,000 tons of steel; 10,000,000 brick; 300,000 square feet of sky-light and 10,000,000 feet B. M. of lumber, which came from the United States. The total floor area under roof, not including office, is 1,315,000 square feet.

The machine shop was the largest of the buildings; it was 427 feet wide and 900 feet long, and was constructed in five bays; the second and fourth bays being clere stories and higher than the other three, and thus allowing for lantern windows.

The two high bays were each 90-foot clear span and had no sec-



CROSS SECTION



ond floor; they were served each with several 50-ton traveling cranes. The other three bays, each 80-foot span, had a second floor, also a mazzanine floor on which were located the lavatories for the men. In this one building there were six hundred wash basins.

The ground floor of this building was paved with asphalt brick, on 12 inches of concrete; the second floors were built of 2x10-inch yellow pine joists, spiked together on edge, similar to grain elevator construction, and floored over with ⅞x3-inch matched flooring, thus making a floor 10⅞ inches thick of solid timber.

The upper sash of all the large windows as well as the lantern sash, were transom sash, and an operating device was put in for swinging them from the floor below, and they were so arranged that generally ten or twelve were connected together. The interior of the entire building was painted with two coats of white oil paint; the work of painting being done by machines operated by compressed air.

There was an installation of 15 direct acting hydraulic elevators put into this building. The machinery for operating these elevators was put in pits under the floor of the shop, and consisted of triple acting pumps, driven by electric motors, and with the necessary open and pressure tanks.

The steel foundry and the iron foundry were buildings almost identical in design. They were 175 feet wide and 570 feet long each. There was a middle aisle of 90 feet clear span, served by 50-ton cranes; on each side of this middle aisle were side aisles each 40 feet wide, and served by 20-ton cranes. Neither of these buildings were paved, the floor being formed in each case by filling in with moulding sand. There was no second floor in either of these buildings, and the entire interior was painted with two coats of white paint. The steel foundry is equipped with two rolling furnaces, of 18-ton capacity each; and with gas producers and core ovens, all of which necessitated considerable fire-brick work. The iron foundry was fitted with four cupolas, and the charging floor was served with three direct acting hydraulic elevators.

The brass foundry was a building 76x570 feet. The ground floor was paved with ordinary brick, and the second floor was constructed as were those in the machine shop—i. e. of 2x10-inch joists on edge, and floored with ⅞x3-inch stuff. This building had four hydraulic elevators.

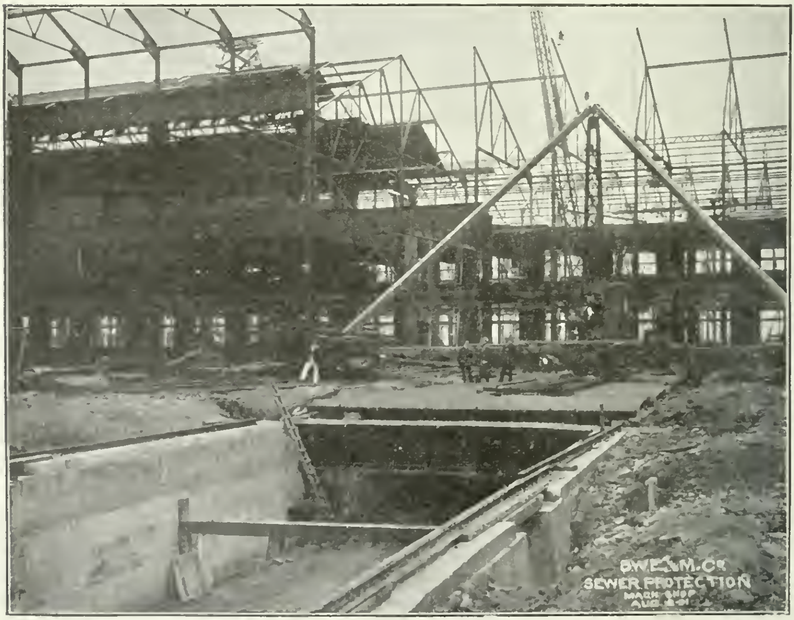
The pattern shop and pattern storage vault, comprised another building the same size as the brass foundry.

One end of this building, for about one-third of its length comprises the pattern shop; this had a second floor and basement. The floor in the basement was of concrete, and the two floors above it were constructed of the 2x10-inch joist laid solid on edge. The other two-thirds of the building had no basement, but had a second floor, which was composed of brick arches sprung between "I" beams, and leveled up on top with concrete; the ground floor was composed by 2x10 inch flooring spiked down to mud sills. The windows in this part of the building were small and far apart, and were protected by self-closing fire-proof shutters. This part of the building was to be used as a vault for the storage of patterns.

The drying and dipping shop, which was a building about 80x160 feet, was constructed in some ways similar to the pattern storage vault, except that the windows were larger. The idea being to make it as near fire-proof as possible, the danger of fire in this building being very great on account of the high temperature which was to be maintained there.

A building 60x250 feet, of construction similar to the rest of the buildings, was erected for a box factory.

There were batteries of six Babcock and Wilcox boilers installed in the power house, which was a building 40x96 feet, and a flue under ground built to the stack. The building had a coal hoist and conveyor, and the boilers had automatic stokers.



Protection of Main Sewer.

The stack had a concrete and brick base. It was of steel, self-supporting and lined with fire-brick; it had a 9-foot flue, and was 165 feet high.

There was a 10-foot brick sewer, belonging to the corporation of Manchester, crossing the site of the work, at an angle of about 15 degrees with the buildings, and passing under four of the large ones. The corporation would not permit the weight of any part of the buildings to come on the ground immediately above or adjacent to this sewer, and it was, therefore, necessary to devise some means of supporting the walls and the columns of the buildings at these points.

Test pits sunk to the sewer, showed the brick work to be in such poor condition that we could not with safety disturb the ground around it. We, therefore, removed the earth on top of the sewer to within three feet of the crown of the arch; and then carried down trenches on each side of and parallel with the sewer to a depth of 30 feet, and in these trenches we built concrete walls, these walls being 20 feet apart. On the line of the walls of the building, and also on the line of each row of columns crossing the sewer, heavy girders were placed across the sewer and built in the walls; these carried the weight of the building. The space between the girders was covered with steel troughing, sufficiently strong to carry a load of 500 pounds per square foot, and on this was placed concrete and paving on a level with the floor of the remainder of the building.

This left a chamber, having about five feet head room, under the girders, access to which was obtainable through man-holes outside the building, affording means both to give the steel work proper care, and to reach the sewer should it ever become necessary to do so.

The office building was 80x250 feet and six stories high, built after approved American fire-proof methods. The exterior presented an ornate appearance and the interior was finely finished in marble, mahogany and oak.

This will give you a general idea of the work which was done. Probably the question,—Why could an American builder, in the face of the fact that he was in a strange country, where labor was more tied down by unions than in this country, and where he might be hindered by the jealousies of men in the same profession, do this work quicker than these same men, has occurred to you?

I have already mentioned that on our arrival at the work we found a complete reorganization necessary, and I have briefly mentioned some of the changes we made. Now I wish to bring some other facts to your attention, and make a few comparisons of English and American methods of doing work, and in so doing try and answer the above question.

The basis on which contracts are let in England is somewhat different from that in use here.

The engineer, or architect, in asking for bids on work, furnishes each bidder with a bill of quantities, specifying the exact amount of each kind of work in the contract down to the most minute detail, thus, in bidding on foundation work, the items would be for example:

Excavation in trenches.

......yds. 0 to 6 ft. deep, ...... per cu. yd.
...... “ 6 “ 12 “ “ ...... “ “ “
...... “ 12 “ 18 “ “ ...... “ “ “
...... “ 18 “ 24 “ “ ...... “ “ “

Excavation in column holes.

......yds. 0 to 6 ft. deep, ...... per cu. yd.
...... “ 6 “ 12 “ “ ...... “ “ “
...... “ 12 “ 18 “ “ ...... “ “ “

Removing excavated material to another part of the site as directed for filling.

......yds. at ...... per yd.

Filling on site with approved material found elsewhere.

......yds. at ...... per cu. yd. ......

Timber in excavation.

Labor fixing and taking out 1 ½-inch boards, including all cutting, walings and strutts, ...... per superficial yd.

Allow for timber necessary.

......cu. ft. at ...... per M cu. ft.

The amount of timber given in bill of quantities was sufficient to shore up all the excavation shown on plans.

Cindering on site.

12 inches thick rolled and rammed
...... yds. at ...... per sq. yd.

Cement concrete.

......yds. at ...... per cu. yd.

Shuttering (forms).

......yds. at ...... per superficial yd.

Having filled in the prices the contractor has but to sum up the total and his bid is complete, thus he is entirely relieved of having to spend any time studying the plans and taking quantities therefrom. If the quantity of the work done is changed for any reason, such as being compelled to go deeper for foundations, the amount due him is changed accordingly.

The concrete was mixed in the proportion of 9 to 1 and pieces of stone, not larger than one man could handle, were allowed to be used, no two pieces being nearer than six inches together. These stones were called plums. The price does not include the forms, or, as they call it, the shuttering, which is paid for separately by the superficial yard.

If one department of our work created more comment and discussion than another, it was the work of our bricklayers. Shortly after we had taken hold of the work, the fact that we were laying 900 brick per man per day was published, and from builders in all parts of the country came the cry "Impossible, the work of our bricklayers does not average over 400 or 500 brick per man per day," and yet later on as the organization became better, and the men became accustomed to our methods, this average of 900 brick per man per day was doubled on the same class of work. So much comment was made on this, that on the construction of a large brick stack, we went so far as to have the foremen make affidavit each night as to the number of brick laid and men employed on this particular piece of work. The men averaged over 1,900 brick per man per day, for a month, and the best day's work was 2,100 brick per man per day.

In this connection I may say that the brick used in this district are larger than those we have here, being 3x4½x9 inches. This record was made possible by providing the most approved hoists for material, so as to have no delay on the part of men waiting for brick or mortar, and by the fact that we used a thinner mortar than was commonly used in England, thus saving time and labor in spreading the beds and setting the bricks in place, and that we were able to get and hold the best men by paying more than the union rate of wages, which for bricklayers is only 20 cents per hour.

I will venture to say, that if you would go to 90 per cent of the contracting engineers or builders in England, and ask, How many brick are you laying per man per day, or just what is your concrete or masonry costing you per yard in place? the answer would be "I do not know."

That such a condition can exist, is made possible by the fact that, considering the cost of material in England, the contracting prices of doing work generally are away above those of doing corresponding work in this country. To my mind this difference in cost represents what is lost by slack method of handling work; not slack as far as quality of the work is concerned, but slack in every other way. It is something which only keen competition, such as we have in America, can overcome.

England has been pre-eminent in so many lines of industry for such a long time, that she has, as it were, been resting on her laurels, not realizing that in other parts of the world tremendous advances were being made along these same lines, and that other countries were assuming an importance in the industrial and commercial world which made England's position uncertain. Some progressive Englishmen realized this long ago, some are just learning the lesson, but the great majority in their conservatism have it still to learn. Go into ninety-nine out of a hundred manufacturing establishments of any kind in England and examine the tools and appliances for doing work. You will probably find the same kind of machines used there to-day which were used and discarded in this country twenty-five years ago. So long as a machine does its work it is satisfactory; the Englishman has not yet come to the point where, by setting down and carefully figuring out his cost account, he finds that it may be economy to discard a machine, even though it is doing good work, and replace it by one which will do that same work quicker and at less cost. It has been well said "The English manufacturer does not know the value of a scrap pile."

The English employer is prone to lay the blame for England's decline in trade on the workman with whom he has to deal, but Mr. Stewart's achievement in Manchester is a shining example of what can be done with the English workman under proper management. Generally speaking, the trouble in England is not with the labor, but with the managers.

Slack management is not, nor can it be, conducive to anything but slackness on the part of those managed.

On the Manchester work at the end of each day, the foremen in charge of the several classes of work, each turned into the office a report showing the progress made that day,—i. e. tons of steel erected, yards of concrete put in, number of brick laid, square feet sky-light put up, etc., covering every branch of trade at work on the buildings as the case might be; and the number of men employed in doing the work.

Thus, at a glance, Mr. Stewart could tell just how much work the men were doing and what the work was costing, and being a man who knows how much work ought to be done, and what work should cost, if things were not going right he took such steps as were necessary to make them so.*

The success, then, of this work, lies chiefly in the high personal influence of Mr. Stewart, and the willing service of those he selected as his sub-managers and assistants, and to the fact that careful records of each day's work were kept and used, and that the most approved machinery was employed to help the work along wherever possible; I mean mortar mixers, concrete mixers, brick hoists, painting machines, and a saw mill sufficiently large, so that no cutting of timber for floors or roofs or fitting of sash was done by hand.

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* Not only was he capable of handling the work himself, but he possesses the greater ability of selecting men as his assistants upon whom he can rely, and then giving them the utmost freedom pertaining to their particular branch of the work. He also possesses the happy gift of association with the employees and so keeping in touch with them that, although a stranger to them, to their customs and strange working rules, very little friction ever occurred.

The effect of this work in England is that Mr. Stewart is welcome, and his methods proclaimed by English builders to be the salvation of that line of work there, and this in spite of the fact that he is to be a most dangerous competitor to them.

There is a future for the American who can go to England and take American methods with him, and while it is to be expected he will meet some opposition at first, yet in the end he is bound to win out.

The Americanization of England, to my mind, is bound to come, and its day is not far distant.

## DISCUSSION.

*Mr. Finley*—Did they compel you to put up scaffolding all around the steel framework?

*Mr. Sloan*—Yes, scaffolding had to be put up wherever there were brick walls.

*Mr. Warder*—Are the verticals in two rows around the building to support the horizontal members, or is one end of the horizontal members supported by the brickwork of the walls?

*Mr. Sloan*—The verticals are larch poles that came down from Norway; they were lapped and lashed with a single rope and then the putlocks are lashed to them and built into the brickwork. There is a great advantage of having scaffolding on the inside of buildings.

*Mr. Taylor*—How do the men go up this scaffolding, carrying up a wall 90 feet high?

*Mr. Sloan*—They go up by ladders altogether. We had hoists for the material; they were on the outside of the building.

*A Guest*—I would like to ask about what time was consumed in this construction and the approximate cost.

*Mr. Sloan*—I went over there with Mr. Stewart in March—a year ago—and I left the middle of last March. The buildings were almost finished when I left. Mr. Stewart did better than he said he would. He said it would probably take him fifteen months and the work was practically finished in a year.

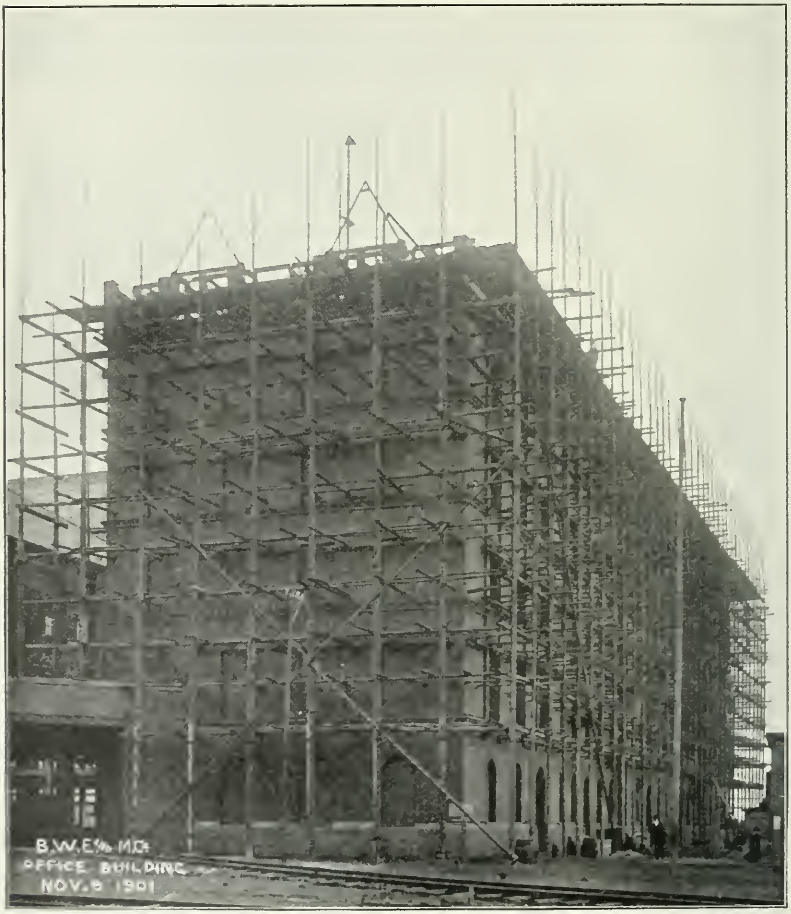
The cost of the buildings, with the machinery installed, was about $8,000,000; without the machinery, about $4,000,000 or $5,000,000.

*Mr. Isham Randolph*—Was the iron work all manufactured in England?

*Mr. Sloan*—All the steel work was of English manufacture; as to the brick, a large part of them were made right on the ground beside the work. The Westinghouse people had a brick yard of their own there.

*Mr. Finley*—Did you get all of those appliances, such as brick hoists, paint sprays, etc., in England?

*Mr. Sloan*—The brick hoists were taken over from this country. They were a special hoist, designed by Mr. Stewart and used by him on the building work which he does in this country. Lidger-



Construction of Six-Story Brick Office Building.

wood engines were taken over as power for running these hoists. The painting machines were of English manufacture.

*Mr. Randolph*—What was the habit of the English people in hoisting their brick?

*Mr. Sloan*—They used the hod.

*Mr. Warder*—I suppose the lumber came from this country largely.

*Mr. Sloan*—Yes, all the lumber used was imported from America. The mill work was also done in America and shipped over, ready to be put in place. This includes all the hardwood finish for the office building. It was made in St. Louis.

The brick walls in the shops were 18-inch and 23-inch walls. In the office building they were thicker.

*Mr. Thompson*—What kind of mortar was used?

*Mr. Sloan*—Lime mortar was used, made of lime, sand and cinders ground in the machines.

*Mr. Thompson*—What is the general color of the brick,—red or yellow?

*Mr. Sloan*—Red, but not a uniform color. A great deal of it was marked with white. The face brick we bought over there and it was of a uniform red color.

*Mr. Randolph*—What became of the tea pots when you started that big boiler?

*Mr. Sloan*—The tea pots were still used.

*Mr. Finley*—Do you think that the methods you used there have left any impression on the English contractors and workmen?

*Mr. Sloan*—Yes, I do. I think this is the beginning of a great improvement over there toward the adoption of better and quicker methods of carrying on building work.

*Mr. Finley*—Did the laying of brick figure out any cheaper than the American bricklaying, considering the wages paid?

*Mr. Sloan*—Yes, it was cheaper.

*A Guest*—How many brick per cubic feet were there?

*Mr. Sloan*—We figured fourteen in our calculations.

*A Lady*—What do they expect to do with the output,—the articles they make there?

*Mr. Sloan*—The immediate need is for equipments of power plants and railways, not only in England but on the continent. Not only in street railways but for electrical appliances of all kinds, England is far behind others in the adoption of such machinery.

*Mr. Taylor*—What was the impression on the minds of those who were furnishing the supplies to Mr. Stewart? Were they prepared to furnish them as rapidly as he wanted them, after having been under the impression that it was going to take five years to finish the buildings?

*Mr. Sloan*—We had considerable trouble in getting even reasonably quick delivery of material, in many cases because our orders were very large, but generally because the dealers were not in the habit of getting things out quickly. There was, however, a remarkable improvement along these lines before we left. When we first arrived there we would call up a dealer on the telephone and order, perhaps, some nails, and, on asking him when he could deliver them, the answer would be, "In a fortnight." After being there a couple of months, his answer to the same question under similar conditions would be, "I'll have them down there in fifteen minutes."

*Mr. Randolph*—Did they ever get it there in fifteen minutes.

*Mr. Sloan*—I think not, but still there was a marked improvement.

*A Guest*—Were the plans altered in any way by Mr. Stewart?

*Mr. Sloan*—It would hardly be expected that in a plant of that size everything would agree exactly, and a few alterations were made, but in general the work was carried out exactly in the way the plans were made.

*Mr. Finley*—Were these plans furnished by American engineers?

*Mr. Sloan*—Mr. Thos. Rodd, of Pittsburgh, prepared all the plans.

*Mr. Love*—Was the work taken away from the English contractors?

*Mr. Sloan*—In cases where the contract had been let before our arrival the contractor was generally allowed to carry out the contract, but a good deal of the work was not let at the time we arrived there and we let it to English contractors generally; in some cases, however, we let work in this country. The copper work was let to an English contractor and we found it necessary to send over here for men—coppersmiths, tinners, etc.—and took the work out of their hands and finished it for them.

*Mr. Karner*—Did the change to American manufacturers cause very much newspaper comment that you know of?

*Mr. Sloan*—Yes, a great deal; mostly along the line of the brick work. This was taken as a basis of comparison in most of the newspaper comments.

*Mr. Taylor*—Did you have much trouble in overcoming prejudice on the part of the English working people?

*Mr. Sloan*—We did have our troubles with the unions there, but by paying the men more than union wages we were able to keep good men all the time.

*A Guest*—Was there ever at any time a scarcity of labor?

*Mr. Sloan*—There was at one time a scarcity of riveters in the steel work and we telegraphed to shipyards up in Scotland and Ireland. Within a day or two we had all the riveters we could possibly use.

*Mr. Finley*—Was it all hand riveting in the field?

*Mr. Sloan*—No, we used pneumatic riveters. That was something we introduced and we had trouble in getting the workmen to use them,—more trouble than with any other thing. They were *very much* prejudiced against the use of the pneumatic riveters.

*Mr. Warder*—Was there any foundation for this prejudice?

*Mr. Sloan*—Simply old time custom. I think you can lay it to that more than to anything else.

## THE TECHNOLEXICON.

The members of the Society and the readers of the JOURNAL, have already had this matter of the preparation of an international polyglot dictionary of technical terms, presented to their attention, (see JOURNAL, Vol. VI, pp. 473 and 578, 1901), but the attention of engineers and others interested in technical matters is again invited to this subject. At the risk of repetition it may be stated that the Society of German Engineers has undertaken to prepare and publish a technical dictionary in the three languages of German, English and French. This dictionary is intended to cover the widest possible range of technical words and phrases in each language, with the corresponding or equivalent expressions in the other of the two languages. To accomplish this the German Engineering Society, through their editor, Dr. Hubert Jansen, invites the collaboration of engineers and technists in this country. In furtherance of this object sundry circulars and note books have been sent to the Western Society of Engineers, for the use of members thereof, (and others), in the hope that they would be used to assist in this very laudable undertaking. These books, etc., will be furnished to those who are willing to collaborate in the preparation of the matter for the Technolexicon.

Another circular has been received from Dr. Jansen which gives examples of how this collaboration should be done. This circular is given here, and it is earnestly hoped that the members of the Society will take an interest in this work, and render some assistance.

### VEREIN DEUTSCHER INGENIEURE.

TECHNOLEXICON:
Technical Dictionary
English-German-French,
Published by the
Society of German Engineers.

TECHNOLEXICON,
Dr. Hubert Jansen,
Berlin (NW. 7),
Dorotheenstr 49.

### COLLABORATION IN THE TECHNOLEXICON EXEMPLIFIED.

#### PRELIMINARY REMARKS.

I. The "Technolexicon" is to be—as the title indicates—a general technical dictionary for the purposes of translation (not an encyclopædia). It will embrace all technical branches.

N. B. Definitions, explanations, and sketches will only be given when absolutely imperative, i. e. especially in the case of dialectical, rare, obsolete, quite new, or little known expressions. To what extent such additions will be included in the dictionary can only be decided after the final moulding of each separate article. In the great majority of cases *either* the exact statement of the speciality *or* the designation of the thing, machine, &c., of which the word under consideration denotes a part, will be sufficient.—Examples:

*Locksmithery:* "rivet" or "bolt" (of a hinge) = German *Dorn* (*eines Scharniers*) = French *lacet* (*d'une charniere*);

*Machine-tools:* "swivel-carriage" = German *Drehsupport* = French *chariot pivotant*.

II. The following communications are addressed partly to societies, associations, authorities, technical colleges, great industrial firms, &c., partly to individual collaborators.

III. The following publications are always kept on hand and may be had on application:

(a) "Introductory Circular," dated March, 1901;

(b) "Objects and Plan of Work" (8 pages), dated March, 1901;

(c) "Extract from the Plan of Work" for Societies, Associations, Authorities, Technical Colleges, Important Industrial Establishments, &c., giving short hints regarding the various ways of collaboration and the acquisition of collaborators, dated October, 1901;

(d) The present circular, "Collaboration in the Technolexicon," dated May, 1902;

(e) The note-books described lower down under B.

IV. Contributions in only one language (*without translation* of the terms given) are also of the greatest value for the Technolexicon.

V. We beg to draw the attention of the reader to the enclosed question-blank. with request to fill it out and return it to the address given at the head of this circular as soon as possible.

### A. VARIOUS WAYS OF COLLABORATION FOR SELECTION.

1. Systematical collaboration, especially on the part of industrial establishments, mining companies, societies, associations, shipping companies, postal, railway and other authorities, likewise on the part of technical colleges (also of the directors, engineers, professors in their specialties), i. e., systematical collection of all the terms occurring in the various technical branches, the actual technical words and phrases,

e. g. in *mining:* "bloomary;" in *foundry practice:* "to slag out."
as well as the words and phrases occuring in the daily work, in the office, the workshop, workyard, &c.,

e. g. in *mining:* "exhaustion," as an office term; "ratter," "to peter out" as terms used in daily work.

This systematical collaboration includes the very important compilation of word-lists, not only for every branch of a concern, but of special lists in each separate department, containing the different parts of each machine, each tool, each product. Likewise the store-lists, inventories, &c , are of high value. A great part of this kind of work can be entrusted to clerks of works, to intelligent foremen and even workingmen.

2. Occasional collaboration, on the part of individual collaborators, i. e. the noting-down of words and expressions occurring in reading or in practical work, in the workshop or office.—Examples:

"to groove for" (two-thirds of the length) = German *einfrasen auf* ($^2{}_3$ *der Lange*) = French *rainurer* [*jusqu'*]*aux* or *entailler sur* (*deux tiers de la longueur*);

"impregnation with resin" = German *Verharzung* = French *impregnation par la resine;*

"washing away" (of land by water) = German *Abflutung* = French *entrainement par l'eau.*

[Chief principles for the systematical and the occasional collaboration:

(a) All words and expressions should be noted down, of which one may assume —without consulting the dictionary—that they are not given in existing dictionaries.

(b) In doubtful cases the word in question should always be noted down.

3 Communication of the titles of technical dictionaries, handbooks, &c., (also older works).

Especially for many handicrafts, for which we can get no collaborators, information regarding manuals and so on is most desirable.

4. Sending in of catalogues and price lists (in one or more than one language) of industrial firms and of publications of all sorts, also those of government authorities, &c.

5. Propaganda for the Technolexicon by means of short articles (based on our printed matter, if convenient) in technical journals, and the continued acquisition of new collaborators among friends, acquaintances, and colleagues

## B. NOTING DOWN OF THE COLLECTED EXPRESSIONS, AND MATERIALS USED THERETO.

1. For the noting down of the words and expressions collected we place specially prepared note books at the disposal of our collaborators.

These note books are divided into three parts (of 60 pages each), each part indexed *A* to *Z*. A short instruction regarding the use is given on the inside of the cover.

N. B. When a note book is filled or has been brought to a provisional conclusion we beg to have it sent to our office. All the remaining note books will be called in by special circular (about the end of 1903).

2. Remarks regarding the noting down;

(a) Of the single words the ground-form should be given (e. g. of substantives the nominative singular, if the word in question can be used in that form).

(b) In compound expressions and phrases that word should be selected as catchword, that is most important for the occasion; e. g. "to beat out the scythe" is placed under "beat," *die Sense dengeln* under *dengeln*, *chapler la faux* under *chapler*.

N. B. It is the duty of the editorial staff (not of the collaborators) to take care that technical words like "scythe" = German *Sense* = French *faux* (already given in the usual dictionaries) are not missing in the Technolexicon.

(c) To save time the collaboraton can use a sign of repetition — for instance ∼ — for the *catchword*, e. g.:

beat *v/a**: to ∼ out the scythe (for to *beat* out the scythe).

## C. SELECTION OF EXAMPLES.

1. Words and expressions in one language (the translation being unknown to the collaborator and missing in the extant dictionaries):

*mining:* roburite, more correct: roborite: (an explosive);
*steam-engines:* overheater;
*railways:* load-limit.

2. Words and expressions with translation:

*electrical engineering:* "autopolar induction" = German *Gleichpol-Induction* = French *induction autopolaire.*

*mechanical engineering:* "stud for bracket" of the Westinghouse brake = German *Hebeltragerschraube* = French *prisonnier du support;*

"lead" of a joint = German *Ganghohe* = French *pas;*

"hinged" = German *umklappbar* = French *monte a charniere,*

*metal-working* and *building:* "expanded metal" = German *Streckmetall* = French *metal deploye.*

3. Phrases with translation:

*machine-tools* (N. B. the catchword is always placed in front):

"control": "to ∼ the direction of rotation" = *die Drehungsrichtung bestimmen* = *commander la direction de rotation.*

"operate": "to ∼ by pinion-shaft" *durch Rader und Welle bewegen* — *commander par l'intermediaire d'engrenages.*

"taper-seat": "to have a ∼" — *konish eingesetzt sein* = *s'emboiter au moyen d'un cone* (or *par un cone*).

"dog"; "the ∼ is always on time" (= "the *tail of the dog* is carried *without play*") — German *das Mitnehmerende wird zwischen den Backen des Mitnehmers ohne Spielraun gefuhrt.*

N. B. The Technolexicon will also devote its attention to the grammatical regimen of verbs, adjectives and nouns, i. e. to the use of prepositions or accompanying cases; for the preposition or case may possibly be expressed very differently in the different languages.—Examples:

"to groove for (two-thirds of length)" = German [*Nuten*] *einfrasen auf* $^2/_3$ *der Lange* = French *rainurer* [*jusqu'*]*aux* (*deux tiers*) or *entailler sur* (*deux tiers de la longueur*); "the speed of the train was increased by 5 kilometers an hour" = *die Geschwindigkeit des Zuges wurde um 5 Kilometer die Stunde erhoht* = *la vitesse du train fut augmentee de 5 kilometres a l'heure.*

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* *v/a* — verbum activum.

4. General technical words that may occur in any technical text:

"working;" as in mining; ~ (of a mine) = German *Betrieb* — French *exploitation;*

"fluctuation in the ~ " = German *Schwankung des Betribes* = French *variation de l'allure;*

" ~ of an apparatus" = German *Betrieb eines Apparates* = French *maniement d'un appareil;*

"hand": "No ~s wanted!" = German *Arbeiter werden hier nicht* (*mehr*) *eingestellt!* = French *On n'embauche pas!*

"capacity for turning out 10 screws a minute" = German *Leistungsfahigkeit von 10 Schrauben die Minute.*

5. Explanations, &c., (only to be given in exceptional cases, see preliminary remark I).

"pad," *cricketing tool*, for protection of the shins and knees. [N. B. Here a short explanation is necessary, because an equivalent is wanting in German and French.]

6. Dialectical words and slang expressions of the various classes and professions, as far as they really belong to technical language or occur at least in technical literature.—Examples:

Cornwall: "to desue" or "dzhu," *verb active* = to cut away [the ground beside a thin vein so as to remove the latter whole];

America and South Africa: "grizzly" (a bar-grating for sizing);

bankers' slang; "stumer" (a forged note or check);

mining slang: "mistress" (a lantern in use in coal mines).

DR. HUBERT JANSEN.

Berlin (NW. 7), Doretheenstr. 49. May, 1902.

M. LASSIG, CHICAGO.

## IN MEMORIAM.

Moritz Lassig died suddenly on Tuesday, January 7th, 1902, in the seventy-first year of his age. He had made all preparations for his departure for Europe and had bidden his friends good-bye, exhibiting considerable emotion in doing so. He intended, accompanied by his wife, to join his two married daughters, Mrs. George (Emma) Bartholomae, and Mrs. August (Ida) Olinger, in Germany, and he did not expect to return. His health had not been satisfactory for years, but death came practically without warning two days before the time set for his departure.

Mr. Lassig was born in Rochlitz, Kingdom of Saxony, in the year 1831. He attended the School of Technology in Chemnitz, and after completing his studies there, emigrated to America, arriving in the spring of 1851. In the autumn of the same year he came to Chicago, accepting a position with the firm of Stone & Boomer

(Andros B. Stone and Lucius B. Boomer, with Amasa Stone, of Cleveland, as special partner). This firm was the owner of the Howe truss patents for certain of the western states, including Illinois. It was the time of the construction of the Illinois and Michigan canal, the Illinois Central railroad, the Chicago & Rock Island railway, and the Galena & Chicago Union railway. The aqueducts carrying the canal over the Fox, Desplaines and other streams between Chicago and the Illinois river, and most of the original bridges upon the aforesaid railroads, as well as upon the railroads generally throughout the western country, were built of this type and by this firm. The works were located between State and Clark, and Fourteenth and Sixteenth streets, Chicago. They were destroyed by fire in October, 1854, and never rebuilt.

Mr. Lassig remained with the firm of Stone & Boomer in positions of increasing responsibility until and during the time of the civil war. He was the valued and trusted assistant of Mr. L. B. Boomer in the execution of the latter's bridge building contracts with the United States government in the states of Tennessee, Alabama and Georgia. After the close of the civil war the bridge building business was continued, with Mr. Boomer, Mr. H. A. Rust and Mr. Lassig as associates under various firm names.

In the year 1876 Mr. Lassig established his own shop on South Clark street near Sixteenth street, Chicago, but these works were soon purchased by the Chicago & Western Indiana railroad for its right of way and had to be abandoned, and Mr. Lassig then formed a partnership with Mr. John Alden under the firm name of Lassig & Alden. Together they leased and operated the Rochester Bridge Works (of Rochester, N. Y.) for five years.

The works of the Lassig Bridge & Iorn Works at Clybourn and Wrightwood avenues, Chicago, were started in 1882. Mr. Lassig was the president, manager, and almost the sole owner. At the beginning these works had an output of approximately 6,000 tons per annum. They reached an output of 42,000 tons in 1900, the last year of their existence as an independent company. In that year they were sold to the American Bridge Company, and Mr. Lassig's connection with them ceased.

Mr. Lassig's success in life was well earned and it was the result of such sterling qualities as honesty, indefatigable industry and painstaking conscientiousness. He had the well-merited reputation of fully and faithfully living up to his obligations and giving full value received in all his dealings. He took great pride in his work; he was always ready to make improvements in his bridge works and had the ambition to make them the best in the country.

He leaves, surviving him, his widow, Marie Lassig, and the two married daughters above mentioned. His remains were interred at

Heidelberg, Germany, where Mrs. Lassig and the two daughters reside.

Mr. Lassig was a member of this Society and of the American Society of Civil Engineers, as well as of various social organizations.

D. J. WHITTEMORE,
AUGUST ZIESING,
CHARLES L. STROBEL, } Committee.

Chicago, July 30, 1902.

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EDWARD J. BLAKE.

IN MEMORIAM.

Edward Josiah Blake was born at Bridgton, Me., November 23, 1858. He entered Maine college in 1875, and graduated with credit in 1879. In the winter of 1879-80, he was employed on the surveys for a railroad between Bridgton and Portland, Maine. In 1880 he entered the service of the Chicago, Burlington & Quincy Railroad Company, at Burlington, Iowa, working for some months on maintenance of way, and afterwards on the surveys of a proposed Kansas City-Chicago line, through a portion of the state of Missouri, after which he was in Chicago a short time working up the results of that survey. In 1861 he entered the service of the Wabash, St. Louis & Pacific Ry. with headquarters at Peoria; in 1883 he was transferred to the Engineer's office of the Wabash Railroad Company at Springfield, Ill., where he remained until 1884, when he again entered the employ of the C., B. & Q. at Chicago as Engineer of Terminals, remaining there until 1887. During this time (in 1885) he married Miss Sofie D. Johnson, who survives him. In the year 1887 he was appointed Chief Engineer of the Missouri Lines of the C., B. & Q. R. R. Company, with headquarters at St. Joseph, Mo., a position which he retained until January, 1890, when he was appointed Chief Engineer of the C., B. & Q. R. R. Company, holding this office until 1899, at which time he was promoted to the position of Consulting Engineer of the Burlington System, a position he held when his untimely death occurred on May 29th, 1902.

These are a few bare facts about Mr. Blake which are scarcely more than mile stones in life's journey. They tell little of the man's real life. He came of a New England family; his father, a doctor well known in the country side, and mother died during his boyhood, and his education was completed at the instance of a good aunt. He took a high stand in his classes, and showed as a young man, as he did afterwards, a more than ordinary love for mathematics and research. He was no book worm, but simply one of those to whom learning was easy and problems of mathematics or science a real pleasure. He was wholesome and vigorous; in fact, a peculiarly sane man, a man without hobbies; he took what came to him with a smile. It was said of him that he had good Yankee common sense; that common sense which did not "strain at a gnat and swallow a camel," and he had with that a New England conscience, an unswerving, deeply rooted intention of doing right—of toeing the mark without bragging about it. He was always punctilious in keeping his engagements, as is well illustrated by a remark once made by him that he "could at least say that he had never kept others waiting," he was particular to be on time.

Mr. Blake became a member of the Western Society of Engineers in Nov. 7, 1894, and might easily have become a prominent one, for he had many friends urging him to accept office, but in this he was modest to a fault, and his name appeared in print as rarely as possible.

He was, indeed, a man of unobtrusive manner, retiring disposition and unpretentious ways. He never put himself forward, never urged his own claims, simply did his best, and let the work speak for itself, and it speaks volumes for his real merit and sterling ability, that he so far gained the confidence of his employers that they, unsolicted, advanced him to the highest position in his profession within their gift. Just before a cruel accident took him off in the full vigor of manhood, full of work well in hand, it seemed to his friends, as, indeed, he expressed himself only a day or two before, as if he was at last receiving credit for a good deal of really valuable work. He had done much, but most of all he had established himself securely in the estimation of his employers. He had long been well thought of, and, at last, he stood proved beyond a doubt as a man not only of technical knowledge and skill, but of good sense, good judgment and infinite tact.

Looking into the future with nothing but pleasure, welcoming the tasks which new and larger undertakings were bringing, he was suddenly taken without warning, without pain; and so, his life was short, and yet he had accomplished more in that short space than is given to most men to do, and he left in the hearts of his many friends a deep consciousness of his sterling qualities.

We have not touched on Mr. Blake's private life, feeling that these are subjects perhaps too sacred for a "Memorial," yet, suffice it to say that Mr. Blake's private life was as unselfish and considerate as those who knew his personality might know it would be. He was a devoted husband, a good neighbor, and a good companion.

F. A. Delano,
E. C. Carter,
August Ziesing.

# ABSTRACT OF THE MINUTES OF THE SOCIETY.

### *SPECIAL MEETING—May 28, 1902.*

A special meeting (No. 473) of the Western Society of Engineers was held Wednesday, May 28, President Finley in the chair, with about sixty members and guests present, including about twenty-five ladies. The meeting was called to order about 8:20 p.m. This being a special meeting, no business was brought before the house, but the Chairman, in a few suitable words, introduced Mr. Wm. G. Sloan, of this Society, who presented a paper describing the buildings, etc., of the British Westinghouse Electric & Mfg. Co.'s plant, at Trafford Park, near Manchester, England. The paper was illustrated by a number of lantern slides, showing features of the plant, progress of construction of the buildings, etc.

Discussion followed from Messrs. Finley, Warder, Taylor, Isham Randolph, Thompson, Love, Karner and Sloan.

The discussion closed about 9:15, after which there was social intercourse among the members and guests until about 10 o'clock.

### *REGULAR MEETING—June 4, 1902.*

A regular meeting (No. 474) of the Western Society of Engineers was held in the Society Rooms the evening of Wednesday, June 4th, with President Finley in the Chair.

The minutes of the meetings of May 7th and 28th were read and approved.

The Board of Direction reported that the following have been elected to membership in the Society:

James Spelman, Chicago, Active.
N. Clifford Ricker, Urbana, Ill., Active.
Jas. C. Grey, Chicago, Active.
Thos. S. Leake, Chicago, Associate.
A. H. Aldinger, Hinsdale, Ill., Junior.
E. C. Hasselfeldt, Chicago, Junior.
Chas. J. Luck, Chicago, Active
John F. Jackson, Houghton, Mich., Active.
Wm. G. Sloan, Pittsburgh, Pa., Junior to Active.
Wm. G. Langenheim, Chicago, Active.
R. H. Heine, Chicago, Active.
Ernest Gonzenbach, Wheaton, Ill., Active.
John L. Hall, Chicago, Associate.
Owen T. Smith, Freeport, Ill., Active.
A. H Neureuther, Peru, Ill , Active.
C. L Krum, Chicago, Active.

The following names, as applicants for membership, were also presented:

Jas N Hatch, Evanston, Ill., Active.
Walter J. Parsons, Allegheny, Pa., Active.
Frank Joe Koza, Chicago, Junior.
John Brunner, Evanston, Ills , Active.
Archibald R. Eldridge, Chicago, Active.
Ben C Rich, Chicago, Active
Wm. Franklin Mann, Kokomo, Ind., Active
J. Holt Gates, Chicago, Active.

President Finley then made a statement in reference to a motion introduced at the meeting of the Society May 7th, relating to the Metric System of Weights and Measures. The question of the action of the Society toward the measure now before Congress establishing this system in the United States had been considered by the Board of Direction at its meeting June 3d, and it was decided to hold a special meeting of the Western Society of Engineers on June 18th for the discussion of this subject. It was the intention also to write manufacturers and those interested in export trade who might be interested in such a bill, inviting them to be present and to take part in the discussion. After the discussion of this subject, the question of the position of the Society toward the bill will be submitted to the members by letter ballot.

The Secretary then presented a letter from Mr. John Ericson, Secretary of the Local Committee of the American Water Works Association, inviting the members of the Western Society of Engineers to be present at the meetings of that association at the Auditorium, June 10-13, inclusive.

The President announced that the Library Committee would like to receive suggestions from the members of the Society as to what books it would be desirable to add to the library.

Mr. C. D. Hill was then introduced, who presented his paper, "Notes on the Designing of Chicago Sewers," which had been printed and sent out in advance. Written discussion of the subject was presented by Messrs. L. E. Cooley and J. W. Alvord. The question was further discussed by Messrs. Benezette Williams, Tratman, Alvord, Finley and Hill.

Meeting adjourned at about 9:40 P. M.

### *SPECIAL MEETING—June 18, 1902.*

A special meeting (No. 475) of the Western Society of Engineers was held in the Society Rooms Wednesday evening, June 18th, with President Finley in the Chair and about 35 members and guests present.

This being a special meeting there was no business brought before the house.

The object of the meeting was to discuss the Metric System of Weights and Measures and the advisability of the passage by Congress of House bill 123. This bill provides that all Departments of the Government, in the transaction of business requiring the use of weights and measurement, except in completing the survey of public lands, shall employ and use only the weights and measures of the metric system, and further, at a later date, that the metric system shall be the legal standard in the United States. The date set for the operation of the bill by the Departments of the Government is 1903, but amended to 1904, and to be generally the legal standard of the United States the date was set at 1904 and amended to 1907..

There was a general discussion of this subject.

Written discussion or opinion was received from Messrs. Eldridge, of Chicago; Tutton, of Buffalo; Sanne, of New York; Macomber, of Chicago; French, of Detroit, Mann, of Kokomo; F. Sargent, of Chicago; H. P. Boardman, of Milwaukee, and Tratman of Chicago.

Verbal discussion followed from Messrs. Liljencrantz, Finley, Tratman, B. B. Carter, Trumbull, Milligan, Pratt, H. B. Boardman, Means, Armstrong, Brunner and Van Der Vaart.

The trend of the arguments was mostly in favor of this country adopting the Metric System of Weights and Measures.

The meeting adjourned about 10 P. M.

### *SPECIAL MEETING—July 9, 1902.*

A special extra meeting (No. 476) was called by the Entertainment Committee for Wednesday, July 9, 1902.

The meeting was called to order about 8:30 P. M. by Past President A. V. Powell, who introduced the speaker for the evening, Charles C. Jamieson, Captain United States Army, Instructor of Ordnance and Gunnery at United States Military Academy, West Point, New York.

Captain Jamieson addressed the Society and guests (about 80 present) on "Armor and Ordnance, Projectiles, use of High Explosives, and the effects when detonated in the front and rear of protective plates." The address was illustrated by about one hundred (100) lantern slides, many of them of great interest, and the address was highly appreciated by those present.

After the adjournment, about 10 P. M., some light refreshments were served.

# THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what, for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc.

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

## Rules to Govern the Conduct of this Directory.

**First.** Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

**Second.** When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon. on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

**Third.** Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

**Fourth.** Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of application, and then taken off and destroyed. A brief abstract of each application, identified by number only, and stating character of position sought and salary expected, will be published in the Journal. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

**Fifth.** Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is hoped that this arrangement of applications, etc., filed at the offices of the Society, will result in benefit to those members who are seeking a professional engagement.

By Order of the Board of Direction.

J. H. Warder, Secretary.

August 5, 1902.

## LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for June, 1902, we have the pleasure to report the following gifts from donors named:

U. S. Treasury Department, Supt. Coast and Geodetic Survey, one volume, quarto, cloth, Report for 1900.

Open Court Publishing Co., Chicago, one cloth bound volume, "Science of Mechanics," by E. Mack.

Prof. J. D. Cormack, Gen'l Sec'y University College, London, two volumes, cloth, Proceedings International Engineering Congress, Glasgow, 1901. Sec. I, "Railways;" Sec. II, "Waterways and Maritime Works."
    One volume, cloth, "Local Industries of Glasgow and West of Scotland."

C. D. Wright, Commissioner of Labor, Washington, D. C., one volume, cloth, 16th Annual Report, 1901, "Strikes and Lockouts."

Peabody Coal Co., Chicago, one wall map and one cloth bound book, List of Shipping (Coal), Mines and Coal Railroads, Illinois and Indiana.

Geo. P. Nichols & Bro., Chicago, trade catalogue of Pawling & Harnischfeger, Milwaukee, "Traveling Electric Hoists."

J. F. Foster, Supt. and Engr. South Parks, Chicago, twenty-four pamphlets, Annual Reports of South Park Commission, 1874-6-8-9, 1882–1901.

Drexel Institute, Philadelphia, pamphlet, Year Book, 1902-3, Departments and Courses of Instruction.

Chas. D. Walcott, Director U. S. Geological Survey, three cloth bound volumes, Parts II, III, IV, 21st Annual Report, 1899-1900.

Massachusetts Commonwealth, Board of Railroad Commissioners, 33d Annual Report, January, 1902, cloth bound.

Lowell, Mass., Water Board, pamphlet, 29th Annual Report, 1901.

University of Illinois, pamphlet, Calendar for 1901-1902.

Chief of Engineers, U. S. War Department, Part 5 of Annual Report for 1901; cloth bound volume, with supplement.

Geo. S. Morison, New York, pamphlet, Address Before the Massachusetts Reform Club, April 24, 1902, on "The Isthmian Canal."

U. S. Geological Survey, Department of the Interior, thirteen pamphlets –
    Production of Fluorspar and Cryolite in 1901, by J. H. Pratt.
    Production of Tungsten, Molybdenum, Uranium and Vanadium in 1901, by Pratt.
    Production of Lithium in 1901, by J. H. Pratt.
    Production of Monazite in 1901, by J. H. Pratt.
    Production of Asbestos in 1901, by J. H. Pratt.
    Peat by Heinrich Ries.
        "The Production of Arsenic in 1891," by Joseph Struthers.
        "Chromite or Chromic Iron Ore," by J. H. Pratt.
        "The Production of Barytes in 1901," by J. H. Pratt.
        "The Production of Graphite in 1901."
        "The Production of Antimony in 1901," by Jos. Struthers.
        "The Production of Talc and Soapstone in 1901," by Pratt.
        "The Production of Bismuth in 1901," by J. Struthers.
        "Production of Aluminum and Bauxite in 1901," Struthers
        "Production of Gypsum in 1901
        "Production of Abrasive Materials in 1901," Pratt.

American Association for the Advancement of Science, circular, Preliminary Announcement of 51st Annual Meeting for June, 1902.

Interstate Commerce Commission, 15th Annual Report, January 17, 1902.

The Iron Age, New York, pamphlet, "The Iron Age Directory, 1902."

Massachusetts Institute of Technology, Boston, pamphlet, Annual Catalogue, 1901-1902.

H. C. Rogers. Vice-President Eddy Valve Co., Waterford, N. Y., trade catalogue for 1901, "Valves, Hydrants, etc."

J. Willard Morgan, Comptroller of the State of New Jersey, Railroad and Canal Reports, 1901; cloth.

Michigan Engineering Society, Climax, Mich., The Michigan Engineer, 1902.

The Institute of Junior Engineers, London, eight volumes, cloth, Record of Transactions, Vols. I, II, IV, V, VI, VII, VIII, IX.

H. B. Herr, M. W. S. E.—

7 vols, quarto, cloth, U. S. Geographical Surveys W. of 100 Meridian, Capt. Wheeler, Vols. I-VII.

1 vol., quarto, cloth, Report by Capt. Wheeler (1885), 3d International Geographical Congress, Venice, Italy.

1 vol., large 8vo, $\frac{1}{2}$ morocco, U. S. Geological Surveys (Capt. Wheeler), Tables of Geographical Positions and Barometrical Altitudes.

2 copies, quarto, cloth, Preliminary Report Exploration Nevada and Arizona, War Department, 1871.

1 vol, quarto, cloth, Astronomical Report, 1874, Explorations and Surveys West of 100 Meridian.

1 vol., quarto, cloth, U. S. Geographical Survey, Capt. Wheeler, January 1, 1875, "Catalogue and Declination of 2,018 Stars."

3 vols., quarto, cloth, 4th, 5th and 6th Annual Reports, U. S. Geological Reports, Powell, 1882-3, 1883-4, 1884-5.

1 vol., quarto, cloth, No. 24 Professional Papers, Corps of Engineers, 1882.

2 vols., 8vo, cloth, Proceedings Engineers' Club of the Northwest, Vol. IV, 1878 9; ditto W. S. E., Vol. V, 1879-80.

3 vols., 8vo, cloth, Reports of Mississippi River Commission, 1881-2-3.

1 vol., paper, Nicaragua Canal, Message from President of U. S. and Representative of Board of Engineers, 1896.

8 vols., $\frac{1}{2}$ roan, Journal Association of Engineering Societies, Vols. V-XII, inclusive.

25 vols, half leather binding, Transactions American Institute Mining Engineers, IV-XVII, XIX-XXVIII, Index XVI-XXV, and one volume plates for Vols. IV-XIII.

63 vols., cloth, Sundry Reports, Chief of Engineers, 1871-1893.

1 vol., cloth, Descriptive Index Engineering Literature.

1 vol., cloth, Mahan's "Stone Cutting and Fortification."

1 vol., $\frac{1}{2}$ roan, Wetherell's Lecture Notes on Chemistry, Bethlehem, Pa., 1863.

1 vol, cloth, Bartlett's Philosophy (Natural), "Acoustics and Optics."

1 vol, sheep, Davis' Descriptive Geometry.

1 vol, sheep, Rust's New York Code of Civil Procedure.

1 blank book ruled for Meteorological Observations, bound in leather.

Macmillan & Co., New York, publishers (for review), 1 vol., 8vo, cloth, "Municipal Administration," by Prof. Fairlie.

J B. Lippincott Co, Philadelphia, 1 vol., cloth, "Water and Its Purification," by S Rideal.

Edward Atkinson, Boston, Mass, circulars, pamphlets, etc., relating to Fire Protection, Slow Combustion, Mill Construction, Inspection of Fire Apparatus, etc., as "Steam Fire Pumps," "Fire Pump Protection," "Underwriters' Fire Hose." "Automatic Sprinklers." "Rules for Dry-pipe System of Automatic Sprinklers," "Rules for Installing Electric Light and Power Apparatus," "Approved Electrical Fittings," "Specifications for Wood Tanks." "Safety Lanterns," Annual Reports for 1899, 1900 and 1901 of the Boston Mut. Fire Ins. Co.; Reports of same Company on "Fire Retardent Materials," "Coal and Coke Evaporation Value," "Tests of Steam-pipe Covering," "On the Diffusion of Light," etc., etc.

E. A. Seitz, International Correspondence Schools, Scranton. Pa., one small leather-bound book, "Mechanics' Pocket Memoranda."

Edward Flad, Water Commissioner, St. Louis, pamphlet, Report Commission of Hydraulic Engineers, 1902.

Perry F. Nursey, Sec'y Society of Engineers, London, four volumes, cloth, Transactions and Index, 1896, 1897, 1898, 1901.

University of Michigan, Ann Arbor, Mich., pamphlet, Calendar 1901-1902.

Geo. S. Morison, New York, pamphlet, Lecture Delivered Before the Contemporary Club, Bridgeport, Conn., May 20, 1902, on "The Isthmian Canal."

New York Electrical Society, New York City, pamphlet, "Power Plants of the Pacific Coast," by A. C. Perrine.

A. Lundteigen, Asst. Mgr., Peerless Portland Cement Co., Union City, Mich., pamphlet, "The Manufacture and Use of Portland Cement."

H. E. Horton, Chicago Bridge & Iron Co., Washington Heights, Ill., pamphlet, "Metal Structures."

American Mfg. Co., New York, pamphlet, "Rope Transmission, 1902."

P. Glasenapp, Engineer Attaché, Imperial German Embassy, cloth bound volume, "The Work of Improving the Waterway of the Rhine, 1851-1900."
One volume, bds., "Measures for the Control of Flood Water in the rivers Memel, Pregel and Weichsel—1902."
One volume, bds., "The Results of the Hydrographic Survey of the Rhine and its principal Tributaries. Vol. VI, the River Main."

J. Willard Morgan, Comptroller, State of New Jersey, Trenton, one pamphlet, Annual Statements of the Railroad and Canal Companies of New Jersey, 1900.

Owen B. Maginnis, Architect, New York City, one volume, cloth bound, "Bricklaying."

D. W. Mead, Chicago, one pamphlet, "Notes on the Selection and Design of Public Works," 1899.

J. W. Midgley, Chairman Western Freight Association, two pamphlets, "Car Service Reform," Chicago, 1902.

Ohio State Board of Health, one volume, cloth, "Fourth Report of an Investigation of the Rivers of Ohio," 1901.
"Fifteenth Annual Report of the State Board of Health for 1901."

American Iron & Steel Association, Philadelphia, one pamphlet. "Statistics American and Foreign Iron Trades for 1901."
"Directory of the Iron and Steel Works of the United States, 1901." By purchase.

C. L. Crandall, Cornell University, Ithaca, N. Y., two pamphlets, "Transactions Association of Civil Engineers, 1901-1902."

General Construction Co, Seattle, Wash., one pamphlet, Trade Catalogue, "Bewsher Sand Pumps and Gold Dredging Machinery."

John Wiley & Sons, New York City, one pamphlet, "Diagrams of Mean Velocity of Uniform Motion of Water in Open Channels," Church.

B. M. Harrod, C. E., New Orleans, La., two pamphlets—
Report Board of Inquiry, Drainage Works, New Orleans, March, 1902."
"Additional Statement of B. M. Harrod on Change of Cement."

U. S. Treasury Department, Washington, D. C., one volume, "A History of the Public Buildings under the control of the Treasury Department. 1900."

Cornell College, Mount Vernon, Iowa, Catalogue 1901-2.

Lewis Institute, Chicago one pamphlet, "Sixth Annual Register, 1902."

Massachusetts Institute of Technology, pamphlet, "Results of Tests made in the Engineering Laboratories of the Massachusetts Institute' of Technology."

Ft. Wayne Electric Works, Ft. Wayne, Ind., pamphlet, Catálogue of Parts of "Wood" Arc Dynamos, March, 1902. No. 2004.

Armour Institute of Technology, Chicago, one pamphlet. Year Book 1902-3.

State University of Iowa, Iowa City, Iowa, one pamphlet, "Announcement of College of Liberal Arts 1902-3."

E. E. R. Tratman, Chicago—
- 2 vols., cloth, New York Railroad Reports, 1901. Vols. I & II.
- 1 vol., cloth, "Commercial Relations of the United States, 1901." Vol. I.
- 4 pamphlets, ' Railways of the Dutch Indies, 1901," "Steam Tramways of the Dutch Indies, 1902," Tenth Annual Report Railroad Commissioners of the State of Texas for 1901; 49th Annual Report of the Railroad Commissioners of the State of Connecticut for 1901.
- One pamphlet, "The Gravity Dam," by E. R. Beardsley, Waldron, Ill., 1902.

Wm. A. Haven, Engineers' Society of Western New York, Buffalo, N. Y., one pamphlet, Membership List, March, 1902.

Elwood Mead, U. S. Dept. of Agriculture, Experiment Station, Washington, D. C., four pamphlets, separate parts of Bulletin 104, "Irrigation Investigations for 1900."
One vol., cloth, Bulletin No. 100, "Report of Irrigation Investigations in California, 1901."

Engineering News Publishing Co., New York, one cloth bound volume, "Municipal Year Book, 1902."

J. F. Wilson, Sec'y, Engineers' Club of Cincinnati, Ohio, "Annual Report for 1901."

Vulcan Iron Works, Chicago, one pamphlet, Trade Catalogue, "Pile Driving Machinery."

Geo. A. Carpenter, City Engineer, Pawtucket, R. I., seven pamphlets, Annual Reports, Board of Public Works, Pawtucket, R. I., 1895-1901 inclusive.

Goheen Mfg. Co., Canton, Ohio, one pamphlet, Trade Catalogue, 1902, "Galvanum."

Foster Engineering Co., Newark, N. J., one pamphlet, Trade Catalogue, "Specialties for Steam, Water, Gas or Air." 1902.

O. H. Tittman, Supt. U. S. Coast and Geodetic Survey, Treasury Dept., Washington, D. C., one book, cloth, "The Eastern Oblique Arc of the United States and Osculating Spheroid." 1901.

Wm. Seafert, Cement & Engineering News, Chicago, four pamphlets—
- "Le Chatelier's Formulas and the Hydraulic Index," by S. B. Newberry.
- "The Commercial Analysis of Portland Cement," by Wm. B. Newberry.
- "Fuel Consumption in Portland Cement Burning," by S. B. Newberry.
- "The Constitution of Hydraulic Cements," by S. B. & W. B. Newberry.
- "How to Use Portland Cement," translated from the German. S. B. Newberry.
- One vol, cloth, "American Cements," by Uriah Cummings. 1898.

U. S. Dept. of Agriculture, Bureau of Forestry, two pamphlets—
- "A Working Plan for Forest Lands near Pine Bluff, Ark.," 1902, by F. E. Olmsted.
- "The Timber Resources of Nebraska," by Wm. L. Hall.

New England Cotton Manufacturers' Association, one book, bds., "Transactions, Annual Meeting April 23-4, 1902."

Wm. B. Phillips, University of Texas, one pamphlet, Bulletin No. 3, "Coal, Lignite and Asphalt Rocks," May, 1902.

F. E. Barker, Pres., Massachusetts Board Gas and Electric Light Commissioners, Boston, 16 pamphlets, Annual Reports 1885-1901 inclusive.

Zeitschrift des Vereines Deutscher Ingenieure, Berlin, Nos. 1 to 23 inclusive, Jan. 4th to May 31st.

W. T. Dunn, Sec'y, Institution of Junior Engineers, one cloth bound volume, Transactions 20th session 1900-1901, Vol. XI.

Iowa State Board of Railroad Commissioners, one cloth bound volume, 24th Annual Report June 30th, 1901.

Massachusetts Railroad Commissioners, one cloth bound volume, 33rd Annual Report, Returns for 1901.

Thos. D. West, Sharpsville, Pa., one cloth bound volume, "Metallurgy of Cast Iron," by Thos. D. West. 1902.

Wm. Bullock Clark, State Geologist, Baltimore, Md.—
- One volume, cloth, "Report on the Highways of Maryland, Dec., 1899."
- One pamphlet, "Laws of Maryland relating to Highways, Dec 1899."
- One pamphlet, "Second Report on the Highways of Maryland, Feb., 1902."

# BOOK NOTES.

**The Block System of Signaling on American Railroads,** by B. B. Adams. The Railroad Gazette, New York. 6x9 inches. Cloth. 251 pp. with many illustrations and insets. $2.00.

It is safe to assume, with the author of this work, that the number of miles of railroad now operated under the Block Signal System will keep on increasing, and it is to be hoped that the element of safety which this device introduces in the operation of railroads will become so clear to the managers thereof, that the rapid strides made in the last ten years in this direction will be marvellously outdistanced in the same or much shorter period in the future.

To the railroad man who wishes to familiarize himself with the workings of the block system, as well as to those whose energies are bent towards its development, this volume can well be recommended.

The reader can get a clear idea of the system in use on the Pennsylvania Railroad, as well as the regulations issued by that company for the government of signalmen, conductors and all concerned.

The departure by the Erie road in adopting the bill code, together with its advantages over the Morse or more complicated code, is briefly and clearly treated by the author.

To get a general idea of the principles which govern the application of the block system to single track roads, the reader has only to refer to the author's description of the practices now in use on the Chicago, Milwaukee & St. Paul Ry. These rules have been recently compiled, or, rather, recompiled, as they differ only from those that preceded them in having embodied the combined results which the different superintendents, after long experience and close observation, recommended for adoption.

The different interlocking machines now in use are very clearly described, which, in connection with the author's treatment of the block signal system, will make the work much more acceptable. E. M.

**Solar Energy.** By. I. W. Heysinger, M. A. J. B. Lippincott Co., Philadelphia, 1901. XL + 348 pp., illustrated. 5x7½ inches. Cloth. $2.00.

All that was, all that is, and all that is to be, in a material sense, is the illimitable field which, under the above title, is discussed by the intrepid author.

The universe is held to be under a regenerative law of reciprocity, which renders impossible the loss or diminution of primal energy upon the manifestation of natural phenomena. It is claimed that this very phenomena, indicative of energy, is incident to the eternal process of maintaining the universal equilibrium which is accomplished without loss.

Electricity is considered the great medium of exchange, and all space as a perfect non-resisting conductor. Under the known laws of electrical polarity, attraction and repulsion, power of chemical composition and disassociation, taken in conjunction with centrifugal force, and modifying general gravity or natural attraction of mass, the author seeks to harmonize all the seeming contradictions of astronomical observations and propounds a theory which he claims to be rationally all explanatory, showing a complete corelation, not only between the movements and conditions of a single solar system with its visitors, but of all systems, solar or otherwise, that ever existed or ever can exist to all eternity.

According to this theory there is no emptiness of space, but all material possibilities are in its extremely attenuated vapors which are all pervading, always have existed and always will exist without bound or limit.

The planets of each system revolving in their atmospheric envelops are great electrical generators or more properly, separators that discharge a continuous electric flow to their respective suns, which in turn shed their wondrous energy of light and heat which is thus induced into the universe to be reconverted or, absorbed into primary vaporose space again.

Thus, while planets revolve without retardation, the author claims that there can be no diminution in solar energy, and also that there can be no retardation, as a resistance to cause such would have prevented the beginning of revolution.

The author disclaims a perpetual motion, so to speak, or a giving forth of that which was never stored or impartial, in-as-much as he claims pregnant "space" to be all containing, eternal, without beginning, end, or limitation, and he but seeks to elucidate the modus by which this all pervading virtue becomes concentrated and "fashioned," not "made," so as to become manifest to human sense and thought. T. C. I.

**Proceedings International Engineering Congress of Glasgow, 1901.** Section I. Railways. 89 pp. Illustrated. Wm. Clowes & Sons, Limited 32 Cockspur street, London.

These proceedings include the nine papers read at the Congress during three days. The Uganda railway is described in a very interesting paper by Sir Guilford Molesworth. This road, built through a previously almost unexplored territory, offered some unique difficulties in railroad location. The data for making the reconnaissance were obtained from the notes of African explorers and a careful consideration of the geological formation of the continent. This was so skillfully worked up that the actual location was made on almost exactly the identical line as proposed by Mr. Molesworth, although three preliminary lines were considered before the final location was made. Added to unusual difficulties of construction was the danger from wild beasts and warlike natives

"The Economy of Electricity as a Motive Power on Railways at Present Driven by Steam," was read by Prof. C. A. Carus-Wilson.

"Modern Practice in Railway Signaling," by I. A Timmis.

A description of the well known Khartoum railway was given by Major C. B. Macauley. Every train on this line that crosses the desert has to carry about ten thousand gallons of water in five special tank cars It was on this line that the famous Atbara bridge was built by an American concern in a remarkably short space of time.

The Australian railways are described by Prof. W. C. Kernot. They are chiefly remarkable for the fact that four different gauges are used on these lines.

"The Proposed Tunnel Between Scotland and Ireland," by James Barton, is an interesting paper. The tunnel as proposed would be about twenty-five (25) miles long under the Irish Channel and 150 feet below the bottom. In the rock to be penetrated no serious difficulties are anticipated in regard to the percolation of water. The cost of the completed work is estimated at $50,000,000. H. C. L.

**Proceedings International Engineering Congress, Glasgow, 1901.** Section 2 Waterways and Maritime Works. 214 pp. Illustrated. Wm. Clowes & Sons, Limited. 32 Cockspur street, London.

During the three days sixteen papers were read by engineers of different countries. Quite a detailed description of the Dortmund and Ems canal is given by Baurath Hermann This canal has a length of 168 miles and is the beginning of the proposed chain of canals to unite the River Rhine with the Elbe. The canal has a depth of 8 feet 2½ inches and a bottom width of 59 feet, the standard dimensions for Prussian canals to be built in the future. The chief engineering feature is the mechanical lift at Henrichenburg, which has a vertical travel of 46 feet and can lift 950 ton barges. The weight of the structure and load is carried by five buoyant cylinders in as many wells. Changing the water level in the wells gives the rise or fall of the lift as desired.

Mr Isham Randolph, M. W. S. E., gave a detailed description of the work on the Chicago Drainage Canal The discussion showed how well the paper was appreciated

"Irrigation in the Nile Valley and its Future," by W. Willcocks, deals with a most interesting subject, especially as it goes into the early history of irrigation as practiced by the ancient Egyptians. In the old form of basin irrigation the flood waters of the river were held back in basins for some forty-five days each year, allowing the subsoil to become thoroughly saturated. In certain localities this water can be drawn on for the rest of the year for the crops The modern system of irrigation makes use of weirs to raise the level of the river at its lower stages. The principal of these works is the great Assuân dam. It is a solid wall of granite masonry 110 feet high. In order to provide against the silting above the dam, 180 sluices are provided, having an area of 24,000 square feet; 475,000 cubic feet per second can be discharged through them. The impounding capacity of the reservoir could be increased two fold by adding 20 feet to the height of the dam, but this would cause the ruins of a near-by temple to become partially inundated. Pressure was brought to bear on the authorities by certain artistic gentlemen, causing the dam to be limited to its present height. The additional height can readily be added when conditions will permit.

"The Improvement of the Lower Mississippi River," by J. A. Ockerson, M. Am. Soc. C. E. This paper brought out an interesting discussion.

"Improvements of the Sulina Branch of the Lower Danube," by C. H. L. Kühl.

"The River Clyde and Harbor of Glasgow," by W. M. Alston.

"Works for Improving the Bilbao River and Making an Outer Harbor. Also the Application of Large Caissons as a Breakwater Foundation," by Señor Don Evaristo de Churruca. This work in the Bay of Biscay, which is subjected to the most violent storms, is an example of modern breakwater construction by means of large monoliths of concrete.

"The Zeebrugge Harbor Works," by MM. J. Nyssens Hart and L. Van Gansberghe, is also an example of modern ocean harbor construction.

"Recent Improvements in the Lighting and Buoying of the Coasts of France," by Baron Quinette de Rochemont.

"The Chinese Lighthouse Service," by J. Reginald Harding.

"Improved Rapid Group Flashing Lights," by Alan Brebner. H C. L.

**The Rotary Kiln.** American Engineering Practice in the Construction of Rotary Portland Cement Plants, as designed and erected by Lathbury & Spackman. Philadelphia. Oblong. cloth, 11¼x9¼ inches. 157 pp., containing many fine illustrations and printed in parallel columns in English. German and French. $2.00. Lathbury & Spackman, Engineers, Philadelphia.

This book describes the manufacture of Portland cement by the rotary process and contains a great deal of valuable information in regard to rotary kilns and machinery connected therewith. It is a very attractive exhibit of the works designed by the above firm and deserves considerably more attention than most advertisements of this class. It is evidently got out largely for foreign distribution and it should be specially interesting to European manufacturers, as it describes the advantages of the American rotary kiln practice and modern cement machinery. It is written in popular language and should prove of much interest to architects, engineers and consumers of cement as well as to cement manufacturers. It is a valuable addition to the cement literature of the day. J. G. B.

**The Municipal Year Book for 1902.** Edited by M. N. Baker, C. E. The Engineering News Publishing Co., New York. Cloth, 6½x9 inches. 364 pp. $3.00.

This is an admirable book of statistics, and is well arranged to give information concerning the public works and services, whether managed by the municipality or a private company, for all incorporated towns and cities of 3.000 or more inhabitants as determined by the census of 1900. There are 54 pages in the introduction containing a summary and discussion, with tables showing the places of over 3,000 population without water works, electric light or telephone service: a list of cities and towns possessing purification plants and character of same, and ownership; a list of places possessing sewage purification, with a supplemental table showing a classified summary of various types of sewage purification. This is followed by a table showing where suits have been brought because of pollution from sewage, and the results of the suit, another table shows the names and population of 97 municipalities making use of cremation or reduction process for disposal of garbage. Another interesting table is that of a list of cities or towns possessing commercial central heating stations, the ownership, and whether independent of or in combination with other public utilities.

The final table, XVIII. shows in a condensed form a list of 1,524 municipalities in order of size from New York with a population in 1900 of 3,437,202 to Rice Lake, Wis., with a population of 3.002, it gives the data of water works. sewers, electric lights, gas works street railways, telephones, central heating plants, etc., etc

The main body of the work has the matter of the last table for each of these public utilities in each of the several cities and towns, stated in detail. These cities and towns are listed alphabetically under their respective states, which in their turn are classified under eight different groups, as New England States, Middle States, South Atlantic States, South Central States, Central Northern States, Northwestern States, Southwestern States and Pacific States. These groups of "States" include the territories also. This detailed information of the several cities and towns shows the population, assessed valuation and principal municipal officers. Also the ownership (whether by the city or a private company) of the several public utilities, the water supply, sewerage, street cleaning and sprinkling, garbage, fire department and disposition of electric wires.

The book is an encyclopedia of municipal news and statistics and every effort appears to have been made by the editor and publishers to have the information correct and up-to-date. W.

**Diagrams of Uniform Motion of Water in Open Channels,** prepared by Prof. I. P. Church, Cornell University, New York. John Wiley & Sons. Paper cover, 9½x12 inches; 11 diagrams and explanations. $1.50.

These diagrams are based on the formula of Ganguillet and Kutter, and are arranged for varying values of n = .009 to n = .035. Also for various hydraulic radii from 0.10 to 25. The slopes used range from 0-01 ft. per 1,000 to 100 per 1,000 ft. These cover the variations in the values of n, r and s that will occur in ordinary practice. The formula of Ganguillet and Kutter, in which occur the factors n, r and s, is an involved one and somewhat tedious to solve. Though the use of these diagrams may not give the refinements of results, to decimals of a foot per second, for the value of v, yet for a good deal of the work that comes to hydraulic and sanitary engineers, the results are quite close enough for use, particularly, when assumptions must be made as to the value of n, and the values of r and s may not be accurately determined. These diagrams therefore will fill a useful place for the ready determination of the velocity v of the flow of water in open channels W.

**Metallurgy of Cast Iron,** by Thomas D. West, author of "American Foundry Practice," "Moulders' Text-book," etc., etc. The Cleveland Printing and Publishing Co., Cleveland, Ohio. Seventh edition, 1902. Cloth, 5x7¾ inches, 627 pp. Fully illustrated. Price $3 00.

This late edition of a valuable and comprehensive book is an "Exposition of the processes involved in its (cast iron) treatment chemically and physically, from the blast furnace, through the foundry, to the testing machine."

Part I consists of 27 chapters, and treats of the manufacture and use of coke, properties of ores used in the manufacture of cast iron, operations of blast furnaces, brands of pig iron with their selection and intelligent use.

Part II, of 21 chapters, tells of the elements in cast iron, and their physical effects, the utility of chemical analyses, and the use of such in the mixing of different brands of iron to obtain gray or chilled castings.

Part III, containing 23 chapters, shows the properties of and the methods for testing molten iron, discloses phenomena in the actions of cooling metal, etc., and presents the results of tests of all kinds of iron and the best methods for testing. This is followed by a series of selected tables of value to those engaged in furnace and foundry work. In this work, the author has covered a very large field and has condensed between the two covers of the book the main principles involved in the manufacture or production of cast iron. Throughout the book the author has shown the secrets for perfection of the material, and thus renders a valuable service to the foundry and furnaceman. The book shows throughout that it has been written by a practical man, who has done a large amount of experimental work. He has clearly outlined the successive steps of the operations, from the charging of the ores into the blast furnace, through the operations of the foundry, to the physical testing machine, used to determine the value of iron; also giving the chemical character required of the material, and the chemical actions which occur throughout the production. It is a valuable text-book as well as a work of reference. J. W. L.

**Bricklaying.** By Owen B. Maginnis. Published by the author, 310 W. 128th St., New York, N. Y. Cloth, 8vo, 85 pages, 148 illustrations. Price $2.00.

This book, with its illustrations, very clearly sets forth the art and practice of bricklaying as applied to various kinds of work. The first three chapters describe the tools used, the setting out and measuring of work, and the mixing of mortar and concrete. Then the practical methods of building brickwork are described, being illustrated by numerous drawings of the various bonds, the arrangement at corners and intersections, etc. The laying up of face work with special brick and ornamental mouldings, etc., is also described, together with the use of colored mortar for such work. Another chapter is devoted to plain and flat arches, gothic arches, and jack arches between I-beams for floors, etc. Flue lining, partitions, and other special kinds of work are also mentioned. Two chapters are devoted to shoring, needling and underpinning. While much of the work described is that of the craftsman or artisan, there is still very much with which the engineer should be familiar, and he will here find it described very clearly and concisely. T.

**Directory of American Cement Industries** and Handbook of Cement Users. Edited by Charles Carrol Brown, Mem. Am. Soc. C. E. Published by the Municipal Engineering Co., Indianapolis, Ind., and New York, N. Y. Second edition, revised and enlarged. 1902. Cloth, 8vo, pp. 740. Price $5.00.

The directory proper covers about 100 pages of which 10 are devoted to the foreign cement trade. Of the various American companies, the location, officers, capacity and brands are given. Following this, there are lists or directories of dealers in cement, contractors and large users of cement, makers of machinery and supplies for cement plants, dealers in lime and plaster, lime manufacturers and plaster manufacturers. These are arranged geographically and cover about 315 pages. Besides these, there are about 60 pages of brief descriptions of individual cement works.

The first 250 pages of the book are of a technical rather than a commercial character. The introduction discusses the growth and development of the cement industry, and shows for recent years a decrease in the use of natural and imported cements and a great increase in the use of American Portland cements. The distribution of cement works in foreign countries is also given. Then comes a paper on the testing of cement, including the reports of the committee of the American Society of Civil Engineers, a board of the U. S. Corps of Engineers, and a committee of the Society of Chemical Industry. A variety of specifications for cement are then given, and a paper on the proportions of cement in concrete, with the strength of concrete; various uses of cement and concrete are then discussed including street foundations, curbing and sidewalks, sewers, tunnel lining, bridges, piers, dams, buildings, etc. These are followed by specifications for the use of cement, or the construction of concrete bridges and other work. Short papers on cement laboratories, lime and plaster, and estimates for cement work, conclude this part of the book. T.

## WORK OF THE UNITED STATES GEOLOGICAL SURVEY.

The following notes are taken from a special bulletin issued in August by the U. S. Geological Survey, and record the progress of certain classes of work which have been undertaken by that department. Further information regarding the matter mentioned may be obtained by application to the Director of the U. S. Geological Survey at Washington, D. C.

**Hydrographic Investigations of the Great Plains.**—For the last two or three years Mr. N. H. Darton, of the Survey, has been engaged in tracing the source of the copious underground waters which appear in the wells of North Dakota and South Dakota. From careful studies of well borings and other geological phenomena of the region, it has been discovered that extensive water-bearing strata underlie the whole plains region and are bent upward and reach the surface on the eastern flanks of the Rocky and Bighorn mountains and in the Black Hills uplift. These strata, known as the Dakota sandstones, are porous rocks, capable of absorbing much water, and are underlain by more impervious carboniferous deposits, which prevent the water in them from sinking lower. Where the water-bearing rocks appear at the surface on the mountain sides they are crossed by many streams, some of whose waters are absorbed by them. These waters follow the rock down under the plains and, at much lower altitudes, in the Dakotas and elsewhere, they appear as artesian waters. This season Mr. Darton, assisted by Mr. C. A. Fisher, has been engaged in continuing the survey of the water-bearing rocks in the Black Hills and Bighorn mountains, and in a reconnaissance of the Great Plains for the preparation of a map showing the general geology and the location of the water-bearing beds of the whole region. The map will also indicate the distance at which the sandstones lie beneath the surface, and the probable depths of the wells necessary to reach them.

**Government Investigations of Pollution in Streams.**—At the beginning of the present season the Division of Hydrography of the United States Geological Survey instituted a branch of research which is expected not only to be of much value to municipalities and numerous industries dependent on the purity of their water supply, but also to exert a beneficial influence upon the health of the general public. The investigation aims to discover the changing conditions of all the important supply streams of the United States by chemical and bacteriological examinations of their waters, and also by measurements of their turbidity and color. The Division of Hydrography has for a number of years been collecting information regarding the volume of flow of the country's streams as a basis for municipal supply, water-power, irrigation, and other uses, but tests for quality and condition have not before been made, except by a few cities which hold an advanced position in matters of public hygiene.

The facts desired, besides turbidity and color, in the present research are, the odor, amount of nitrogen as albuminoid ammonia, free ammonia, nitrites and nitrates, the amount of chlorine, the total residue, the alkalinity, the normal hardness (or incrusting constituents), the amount of carbon dioxide, and the number of bacteria per cubic centimeter. For some localities and for special work the amount of iron will be determined, and, when conditions appear necessary, examinations will be made for microscopic organisms.

In order to secure results from as many localities as possible, supplemental assistance is being rendered by many individuals and organizations, and details are worked out through examinations made in local laboratories. To secure uniformity in these results and to bring them together for comparison and study, the Geological Survey has issued a circular outlining in some detail methods of procedure to be followed by all cooperating workers. The methods recommended for the chemical and bacteriological examinations are those adopted by the committee of the Public Health Association. For uniformity in the measurement of color and turbidity a second circular has been issued, defining standards of measurements which have been adopted by the Geological Survey in cooperation with eminent hydrographic engineers, and also describing methods of procedure. The determination of turbidity is to be made by what is known as the United States Geological Survey turbidity rod of 1902, an apparatus combining the best features of the "platinum wire" and the "silica" standards; and for the convenience of field work, tests for color will be made by comparing samples of water in platinum tubes fitted with glass ends with colored disks of glass rated to correspond with the usual platinum-cobalt standard.

The work is in the hands of Mr. M. O. Leighton, who is at present engaged in an investigation of the rivers of the central western States.

# WESTERN SOCIETY OF ENGINEERS

Secretary's Office, Library, Reading Room and Meeting Room
1734-41 Monadnock Block, Chicago

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Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August

Board of Direction—The Tuesday preceeding the 1st Wednesday of each month.

## NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the Journal

The Fall Meetings will begin Wednesday, Sept. 3, when Mr. W. J. Karner will read a paper prepared by Mr. E. L. Corthell on "Engineering in Argentina"—to be well illustrated

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## CLII.

# NOTES ON DESIGNING CHICAGO SEWERS.

By C. D. Hill, M., W. S. E.

*Presented June 4, 1902.*

One of the most discouraging problems a young engineer has to solve is to determine the proper size of a sewer to drain a given territory. The more conscientious he is, the more he studies the rainfall of the district, its probable development, and especially the more he studies different authorities and applies the different run-off formulæ to the problem with widely differing results, the more confused he becomes. If he can find sewers already built in the neighborhood that have been proven to be satisfactory he will probably exercise his best judgment and conform to local practice, trustins that his errors in the matter will not be discovered until after hig share in the matter has been forgotten.

All of this was well illustrated in a paper presented to this Society three years ago by Mr. Edwin Duryea on "Tables of Excessive Precipitations of Rain at Chicago." This paper brought out a very interesting discussion on the subject of run-off formulæ, and one paper of great value presented by our fellow member, Mr. John W. Alvord, showed the impossibility of any theoretical formula being applicable to all conditions and all localities. Some of the information contained in that paper is incorporated in this, for which due acknowledgment is hereby made.

At that time the writer was struggling with a similar problem, being called upon to design a system of sewers to drain a tract of about 11,000 acres of land in the southern part of this city, and the only advantage he had was the privilege of following precedents in the same vicinity.

Realizing the great importance of obtaining exact data on the subject, he was in hopes that he would be able to make careful measurements of the discharge of several of the principal sewers of Chicago, and to determine not only the flow of sewage during periods of dry weather, but as well the run-off from the districts drained during storms, and then by tabulating the rainfall, acreage, percentage of impervious surface, density of population, etc., be able to present to this Society some information of scientific value.

Unfortunately a multiplicity of duties relating to other matters and the meagerness of appropriations by the City Council made any such investigation impossible. However, there was an opportunity of making a record showing certain facts and conditions from which may be derived conclusions concerning the necessary capacity of sewers proposed to be built in this vicinity. This record, though crude and in many respects inaccurate, is presented for what it is worth.

In the paper by Mr. Alvord, referred to above, some tables gave data regarding certain sewer districts in the city of Chicago, with the further statement that so far as was known these sewers had never flowed full, and consequently the inference was drawn that although some of these sewers had a remarkably small capacity per acre drained, they were properly designed and were entirely adequate.

Three years of experience in the Bureau of Sewers has brought to the writer many complaints of defective drainage and back-water from sewers in times of heavy rainfall. These complaints have been noted and investigated by subordinates, and although in many cases the cause has been largely or wholly due to deposits and obstructions in the sewers, or to the fact that the floors of the basements have been below the level of the tops of the sewers, in other cases the cause is undoubtedly due to the small size of the sewers.

Notwithstanding the great number of complaints made and the opinion current in some quarters that Chicago sewers are all inadequate, it is a fact that many of the sewers in this city are of sufficient capacity and do their full duty.

From the experience thus gained the writer has compiled the accompanying table and diagram. In the case of each sewer noted the area drained has been computed, and this in itself is indefinite, since each system of sewers is connected with adjacent systems. The capacity of each sewer flowing full has been calculated according to Kutter's formula, using the coefficient $n = .013$. This is on the assumption that the sewer is clean and in good order. Dividing the capacity by the acreage gives the rate in cubic feet per second per acre, represented by "q" in the run-off formulæ. Platting these values on the diagram with the horizontal ordinates representing the acreage, and the vertical ordinates the rate per acre, we are able to compare the different sewers with each other and with the curves representing the different run-off formulæ.

The location of each sewer is indicated by the initial letter and number which refer to the accompanying table.

The character of the district is very roughly indicated by a symbol; districts that are very densely settled, such as the territory south of Diversey boulevard, north of 47th street and east of Western avenue, are indicated by a square. Semi-urban districts, such as Hyde Park and Lake View, are indicated by a triangle, and sewers in outlying districts that are undeveloped, so that no conclusion can be drawn as to the adequacy of the sewers, are indicated by a circle. Some of these sewers, although fully equal to the present requirements, will probably prove to be too small in course of time.

The horizontal dash *over* the initial letter and number indicates that the sewer has been found inadequate, and the mark *under* the letter and number indicates that experience shows that the sewer has sufficient capacity.

In the table are given approximately the density of population and the percentage of impervious surface of the districts. Since these conditions are constantly changing any great accuracy in this respect would be of little value. Indeed, a general knowledge of the localities would give one a better idea of the conditions than the most exact mathematical statement of population and imperviousness.

The following run-off formulæ are platted:

No. 1. $q = .8A^{-.25}$

No. 2. $10 \log D = 3 \log A + \log N + 68$

No. 3. $q = A^{-1} + .4A^{-.25} + .02$

No. 4. $q = .4A^{-.25}$

No. 5. $q = A^{-1} + .2A^{-.25} + .03$

No. 6. $q = .07$

In these formulæ $q$ = rate in cubic feet per second per acre.
$A$ = area drained in acres.
$D$ = diameter of sewer in inches.
$N$ = distance in which the slope of the ground falls one foot.

No. 2 is the Hawkesley formula and is platted by assuming the slope of the ground to be the same as the gradient of the sewer and that the latter is taken in accordance with the standard practice in Chicago so as to give a velocity of about three feet per second when flowing full. For sewers over five feet in diameter $N = 2500$.

No. 1 is the Burkli-Ziegler formula with a slope of 1 in 1,000, a rainfall of 1 inch per hour and a coefficient .8 for the character of the area drained. The curves No. 1 and No. 2 practically coincide for small areas, and the divergence is due to the difference in the assumed slope.

Formula No. 4 is the same as No. 1 with the coefficient .8 reduced to .4.

Formulæ No. 3 and No. 5 are modifications of No. 4. The first term is arbitrarily added to give increased values of q for small curves, and the third term is added to provide for the constant flow of sewage as well as to increase the value of q for very large areas. It will be noted that all the sewers platted below curve No. 5 are too small and there are but few such above it, the exceptions being sewers in densely settled districts.

Formula No. 6 is a straight line formula and provides for a uniform run-off of 1½ inches of rainfall in 24 hours, and 5,000 gallons of sewage per acre per day.

## HISTORICAL SKETCH OF THE DEVELOPMENT OF CHICAGO SEWERS.

The first sewers of Chicago were designed by Mr. E. S. Chesbrough, the first City Engineer of Chicago, and his assistant, Mr. W. H. Clarke. These sewers were designed in accordance with the Hawkesley formula, and experience has proven them to be entirely adequate. Some of these sewers are indicated on the diagram A. 1, A. 5, C. 1, C. 4, H. 2, M. 5, N. 1, P. 1, R. 6, R. 7, T. 5, and V. 2. The area drained by none of these sewers exceeds 400 acres, and in no case is it less than 100 acres. While it is not believed that the usefulness of this formula is confined to the above limits, it is quite likely that for very large areas of densely settled territory the formula would give too low results, and experience has shown that in the heart of the city, sewers designed on a more liberal basis are barely sufficient to drain small areas.

For example, the sewer in Jackson boulevard east of the river drains 30 acres and has a capacity per acre of 0.56 cubic feet per second, while formula 2 would require but 0.35 cubic feet per second. This sewer has been known to be surcharged by a rainfall lasting but 30 minutes at a rate of 1.75 inches per hour. The small tile sewers in the same district have a capacity per acre of 1.75, and it is uncertain whether the backwater complained of is due to the flooding of the outlet sewers or to the discharge of roof water under pressure into the same house drains that are connected with the basements.

In 1873 Mr. Clarke designed and built a sewer in 35th street west of the lake that shows an unfortunate divergence from the former standard. At that time the district to be drained was as sparsely settled as was Hyde Park 15 years ago, or the northern part of Lake View today, and with a porous, sandy soil it is not strange that the designer should have reduced the capacity of the sewer by 25 per cent. The result is that every heavy rainfall floods the basements in this district.

Soon after the death of Mr. W. H. Clarke in 1878, two large sewers, each 9 feet in diameter, were built, one in West 22d street, extending west from Western avenue, and one in Armitage avenue, extending west from the river. In a general way these sewers and the system of sewers served by them were planned by Mr. Clarke, but it is not known to the writer whether the size of these sewers as finally built was determined by Mr. Clarke. In both cases the territory to be drained was very sparsely settled, and it is believed that a very considerable area has since been added to the district intended to be drained by the sewer in West 22d street. The sewer in Armitage avenue is as yet adequate for the sparsely settled district it serves, but the sewer in 22d street is entirely inadequate. Reference to the diagram shows that the capacity of this sewer (T. 1) should be increased 25 per cent to bring it up to the standard of formula No. 2 and it would probably need to be increased 50 per cent to make it sufficient for the present needs.

Another group of sewers that causes much annoyance and damage are those in 56th street (F. 5), 51st street (F. 6), 45th street (F. 7) and 40th street (F. 8) west of Lake Michigan. These sewers were built by special assessment by the village of Hyde Park about 20 years ago. It is not known by whom these sewers were designed nor in accordance with what formula, but it is more than likely that the size of the sewers was determined, not by the amount of rainfall. but by the amount of money that could be obtained from the property owners. Doubtless those interested felt less anxiety concerning the future population than they did concerning their ability to dispose of their real estate. Until ten years ago these sewers were quite adequate. The great increase of population and of paved areas has so increased the burdens of these sewers that complaints of flooding are very frequent, except in the case of 51st street, which still drains a sparsely settled district. It will be noticed in the diagram that these sewers lie below and close to the curve No. 5.

All of the main outfall sewers in what was formerly Lake View were designed and built before that territory was annexed to the city of Chicago. The first of these sewers was that in Fullerton avenue east of the river. At the outlet (F. 3) this sewer is fairly large, but at Ashland avenue (F. 4) it is reduced in capacity to an unreasonable degree. This district has become densely settled and the sewer has become entirely inadequate. Its capacity should be double what it is. The capacity of the sewer in Diversey boulevard (D. 4) east of the river is fairly large. The territory has not yet developed sufficiently to prove the sewer too small, and this may never occur. The sewer in Western avenue north of the river (W. 2) drains a district that is still sparsely settled, but the capacity of the sewer will undoubtedly prove too small. In like manner the sewer in Robey street north of Roscoe street (R. 4 and R. 5) will prove to be too small when the district drained is more densely settled.

The sewers draining into the lake in the northern portion of Lake View (B. 1, F. 2, G. 1, and L. 1) were designed on a more liberal basis. These sewers have always been sufficient in capacity and will probably remain so. In the diagram these sewers are platted close to curve No. 3. The sewer in Roscoe street ( R. 1 ) is platted below the curve and experience has shown it to be too small. The sewer in Belmont avenue west of Lake View avenue (B. 2) has been the cause of many complaints, but these are due largely to the fact that, the street grades being low, the basements are too deep to be properly drained. This district is more densely settled than those farther north.

When in 1889 the area of the city of Chicago was greatly increased by the annexation of the adjacent municipalities, it became the duty of the Superintendent of Sewers, the late Mr. O. H. Cheney, to plan several large sewer systems for the outlying portions of the city. The conditions being so different from those in the old city and influenced, no doubt, by precedent in the case of the West 22d street, Armitage avenue and 35th street sewers, as well as by the fact that the existing sewers in the newly annexed territorities were of small capacity, Mr. Cheney decided in a general way to plan the sewers large enough to carry off in the course of 24 hours one-half of a rainfall of three inches, and in addition the sewage of a population of 50 people per acre at the rate of 100 gallons per capita per day. In accordance with this theory (indicated on the diagram by formula No. 6) sewers were built in 70th street (S. 4) and 73d street (S. 5) west of Lake Michigan and Wentworth avenue north of the Calumet river (W. 1). Later a sewer was built in South 45th avenue north from the west fork of the south branch of the river (F. 1). Also sewers in Irving Park boulevard, Montrose avenue (M. 2) and Lawrence avenue (L. 1) west of the river. None of the districts drained by these sewers has developed sufficiently to show that the theory on which they are designed is erroneous. This method has been continued by Mr. Cheney's successors and two or three outfall sewers built during the past three years have been designed on the same theory. On the face of it this formula seems absurd. The rainfall, three inches, is too great for this locality and the time allowed, 24 hours, for the rain to run off is also too large. Again, the assumption of the same rate for large and small areas is contrary to the general experience of engineers. For very large areas, sparsely settled and with a small percentage of impervious surface, this formula will undoubtedly give satisfactory results, but it is a great mistake to apply it, as has been done, to the small areas included in a large district. Although this formula has been rigorously applied in determining the sizes of the successive sections of a main outfall sewer, yet the small lateral sewers have always been designed on a more liberal basis. Many of these lateral sewers are of brick, 24 inches in diameter. Few of them drain more than 40 acres; most of them drain from 20 to 30 acres. The capacity of these sewers ranges from 0.20 to 0.40 cubic feet per second per acre. The 15-inch tile sewers drain from 10 to 15 acres each and the 12-inch tile sewers drain from 5 to 10 acres and have a capacity of from 0.30 to 0.40 cubic feet per second per acre. Referring to the diagram it will be seen that these sewers are platted close to the curve No. 3. In the older parts of the city, where the outfall sewers were designed in accordance with the Hawkesley formula, the 24-inch brick and 12-inch tile laterals have more than twice this capacity and if platted on the diagram would lie somewhat above the curve No. 2.

These tile sewers constitute nearly one-half the mileage of the sewer systems of Chicago, and while the evidence offered by them is largely negative, that is very few of these sewers having been proven inadequate, the writer would not venture to exceed the maximum limits indicated above save in rare cases where the local conditions were exceptional. It is for this reason that the first term was added to each of the formulæ No. 3 and No. 5 in order to make the curves pass near the points where the small laterals are platted.

## THE INFLUENCE OF SLOPE.

In the foregoing little has been said concerning the influence on the rate of run-off caused by the slope of the surface of the ground. Most of the territory within the limits of the city of Chicago is very flat and as a rule the difference in the slope can be disregarded. In fact it is somewhat difficult to say what is the rate of slope. In the Hawkesley formula the factor N is the rate of slope along the line of the sewer, while in the Burkli-Ziegler formula the slope is taken along the water courses leading to the inlets to the sewer. The latter is much more rational. In applying the Hawkesley formula to Chicago the slope has been taken as parallel to the slope of the sewer and the value of N for large sewers has been taken as 2,500. If the same slope had been assumed as in the case of the Burkli-Ziegler formula and N taken as 1,000 the curve in the diagram would have been platted considerably higher and the values indicated for large areas would likely be sufficiently large. In determining the rate of slope to apply to the Burkli-Ziegler formula, the natural slope of the ground should not be considered so much as the actual slope of the surfaces, artificial or otherwise, over which the water is to pass. Although the natural surface of the ground may be absolutely level and the established grade of the street pavement be also level, the minimum gradient of the gutters leading to the sewer inlets will be 4 or 5 feet per 1,000 and the slope of the pavement, walks and especially the roofs greatly exceed that amount. In the densely settled portions of Chicago the actual average slope of the surfaces shedding water is much nearer 10 per 1,000 than 1 per 1,000.

We can derive very little data from our experience with the sewerage of Chicago from which to theorize on the effect of slope on the rate of run-off. The most we can do is to compare the experience of Chicago with that of other cities. In Chicago in densely settled districts with a population of 80 per acre and 80 per cent of the surface impervious, with an actual slope of 5 or 10 per 1,000 we find that the sewerage is adequate when designed on a basis of $q = .8 A^{-.25}$.

In St. Louis, New York, Baltimore and Washington, D. C., we find that sewers must be built with three times as great a capacity. The formulæ used in these cities differ slightly from each other, but are substantially equivalent to $q = 2.50 A^{-.25} S^{.25}$. This great difference in the amount of run-off between Chicago and St. Louis cannot be wholly accounted for by the difference in rainfall, nor by the alleged fact that the inlets to Chicago sewers do not admit surface water readily. At least a considerable portion of this difference must be due to the fact that the slope of the surface of St. Louis is much greater than that of Chicago, and the formula used does not give that factor sufficient weight. In all hydraulic formulæ the factor of slope is affected by the exponent ½ and in a run-off formula it should have as much weight, if not more, for the reason that an increased slope reduces the capacity of pervious soils to absorb water, and diminishes the volume of the depressions that retain the water. In other words, the water will not only flow more rapidly to the sewer inlets, but a less amount will be required to fill up depressions and form a "water carrier" and a less amount will be absorbed by the pervious soil.

## CONCLUSIONS.

In drawing conclusions from the data herein given we should remember that these data are all crude and inaccurate, and we should also remember that the best data we can obtain regarding any district that it is proposed to drain are likewise inaccurate. And although by great care we can obtain accurate data as to the present condition of the proposed drainage district, the future condition is an unknown quantity. Therefore our conclusions must be drawn broadly, and these conclusions must be applied to new problems with great discretion. These conclusions apply only to the vicinity of Chicago.

While the venerable Hawkesley formula is entitled to great respect and honor on account of its successful application to the sewerage of this and other cities, yet on account of its form and because it does not properly take into account the slope of the ground it should be retired, as indeed it has been for many years.

In designing a sewer to drain very small areas that are completely paved and roofed we should allow for at least one inch of rainfall in 30 minutes, and in addition allow liberally for all water that may be actually used on the premises for manufacturing or otherwise. In this connection it may be said that the city water used in the tall office buildings in one day is equivalent to a volume covering the area of the buildings and 7 inches in depth.

For similar areas of 5 to 50 acres the rate per acre may safely be diminished in accordance with the Burkli-Ziegler formula, using a coefficient 2.00 and assuming the slope as 1 in 1,000.

For large areas densely settled, but not completely paved and roofed, formula No. 1 would be safe.

For semi-urban districts, where the percentage of impervious surface will not exceed 40 per cent, formula No. 3 would probably give good results, and in rural districts, where the percentage of impervious surface will not exceed 20 per cent and the population 10 or 15 per acre, and the low value of the land not warrant a large expenditure, formula No. 5 might be employed.

Instead of using one or more of these formula in a rigid manner it would be much better to study carefully the conditions of the proposed district, taking into account its probable future, and then, comparing the district with others platted on the diagram, assume a rate per acre for the whole district in accordance with your best judgment, modifying the rate for the smaller subsidiary areas in a general way in accordance with the curves No. 1, No. 3 or No. 5. In other words, construct on the diagram a curve that is suitable for the particular problem to be solved.

## CHICAGO SEWERS.

| | Location of Sewer. | Area Drained in Acres. | Population per Acre. | Area Impervious. | Cubic ft. Sec. per Acre. | Capacity of Sewer. |
|---|---|---|---|---|---|---|
| A. 1 | West Adams St., West of River | 266 | 70 | 90% | 0.200 | Adequate |
| A. 2 | Armitage Av., West of River | 3230 | 40 | 30% | 0.080 | Adequate as yet |
| A. 3 | Adams St., East of River | 30 | 1500 | 100% | 0.560 | Few complaints |
| A. 4 | Addison St., East of Robey St | 300 | 30 | 30% | 0.147 | Adequate |
| A. 5 | Augusta St, West of River | 196 | 120 | 90% | 0.260 | |
| B. 1 | Bryn Mawr, West of Lake Michigan | 275 | 10 | 20% | 0.120 | Adequate |
| B. 2 | Belmont Av., West of Lake View Av. | 85 | 60 | 50% | 0.200 | Basements flooded |
| C. 1 | N. Clark St., North of River | 400 | 90 | 80% | 0.220 | Adequate |
| C. 2 | Clybourne Pl., East of River | 180 | 90 | 40% | 0.160 | |
| C. 3 | Chicago Av., West of River | 48 | 100 | 90% | 0.330 | Adequate |
| C. 4 | Chicago Av., East of River | 108 | 120 | 90% | 0.250 | Adequate |
| D. 1 | Dearborn St., Randolph to Madison | 1.75 | 1500 | 100% | 1.710 | Few complaints |
| D. 2 | Division St, West of River | 367 | 100 | 90% | 0.140 | Doubtful |
| D. 3 | Division St, East of River | 50 | 10 | 40% | .330 | Adequate (Goose Island) |
| D. 4 | Diversey Boul, East of River | 675 | 30 | 40% | .113 | Doubtful |
| E. 1 | Erie St., West of River | 33 | 100 | 90% | .500 | Adequate |
| F. 1 | S Forty-fifth Av., North of River | 3800 | 40 | 30% | .760 | District undeveloped |
| F. 2 | Foster Av., West of Lake Michigan | 265 | 10 | 20% | 0.120 | Adequate |
| F. 3 | Fullerton Av., East of River | 550 | 60 | 60% | 0.110 | Doubtful |
| F. 4 | Fullerton Av., East of Ashland Av. | 500 | 70 | 60% | 0.064 | Frequently flooded (same outlet as F. 3) |
| F. 11 | Fullerton Av., East of Sheffiled Av. | 200 | 70 | 70% | 0.085 | Frequently flooded |
| F. 5 | Fifty-sixth St., West of Lake Michigan | *1100 | 20 | 30% | 0.036 | Frequently flooded |
| F. 6 | Fifty-first St., West of Lake Michigan. | 900 | 20 | 30% | 0.066 | Barely adequate now |
| F. 7 | Forty-fifth St., West of Lake Mich. | 500 | 40 | 40% | 0.058 | Frequently flooded |
| F. 8 | Forty-first St, West of Lake Mich. | 410 | 50 | 40% | 0.070 | Frequently flooded |
| F 9 | Forty-first St., West of Prairie Av. | 93 | 40 | 40% | 0.170 | |
| F. 10 | Fullerton Av., West of River. | 1010 | 30 | 50% | 0.100 | |
| G. 1 | Granville Av., West of Lake Michigan | 425 | 10 | 20% | 0.140 | Adequate |
| G. 2 | Graceland Av, West of Lake Michigan | 160 | 10 | 10% | 0.038 | Few complaints |
| G. 3 | Garfield Boul., West of Michigan Av. | 90 | 20 | 30% | 0.210 | Discharge into Fifty-sixth St. sewer |
| G. 4 | Garfield Boul, East of Michigan Av. | 155 | 20 | 30% | 0.140 | Complaints due to outlet |
| H. 2 | Harrison St., West of River. | 260 | 80 | 90% | 0.200 | Adequate |
| I. 1 | Indiana Av., South of Garfield Boul. | 45 | 20 | 30% | 0.200 | Sec. G. 3, G. 4 and F. 5 |

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| I. 3 | Irving Park Boul., South of Robey St | 203 | 30 | 30% | 0.180 | Adequate |
| L. 1 | Lawrence Av., West of Lake Michigan | 370 | 10 | 30% | 0.122 | Adequate |
| L. 2 | Lake Av., North of Forty-fourth Pl... | 26 | 50 | 40% | 0.250 | Backwater from outlet F. 7 |
| L. 3 | Lawrence Av., East of Robey St. ... | 162 | 20 | 30% | 0.160 | Adequate |
| L. 4 | Lawrence Av., West of River.... | 1300 | 3 | 30% | 0.065 | District undeveloped |
| L. 5 | Lake View Av., North of Roslyn Pl.. | 7½ | 50 | 40% | 0.360 | Too small—slope 16 in 1000 |
| M. 1 | Michigan Av., River to Van Buren.... | 58 | 500 | 90% | 0.200 | No complaints |
| M. 2 | Montrose Av., West of River.... .... | 1450 | 5 | 10% | 0.080 | District undeveloped |
| M 3 | Michigan Av., South of Garfield Boul. | 54 | 20 | 30% | 0.130 | Sec. G. 4 and F. 5 |
| M. 4 | Montrose Av., East of Robey St..... | 170 | 20 | 30% | 0.160 | Adequate |
| M 5 | Madison St., West of River......... | 280 | 90 | 90% | 0.185 | Adequate |
| N. 1 | North Av , West of River ........... | 310 | 80 | 90% | 0.250 | Adequate |
| N. 2 | North Av., East of River............ | 380 | 80 | 90% | 0.105 | Unknown |
| P. 1 | Polk St., West of River............ | 131 | 120 | 90% | 0.210 | Adequate |
| R. 1 | Roscoe St., West of Lake Michigan... | 170 | 30 | 40% | 0.100 | Deep basements flooded |
| R. 2 | Robey St , North of Montrose Av... | 450 | 20 | 20% | 0.077 | District undeveloped |
| R. 3 | Robey St , North of Byron St,...... | 870 | 20 | 20% | 0.068 | District undeveloped |
| R. 4 | Robey St., North of Roscoe St....... | 1260 | 20 | 20% | 0.076 | District undeveloped |
| R. 5 | Robey St., North of Addison St...... | 1100 | 20 | 20% | 0.054 | District undeveloped |
| R. 6 | Rush St., North of River............ | 290 | 90 | 80% | 0.260 | Adequate |
| R. 7 | Randolph St., West of River......... | 275 | 60 | 90% | 0.190 | Adequate |
| S. 1 | Sheridan Road, North of Lawrence Av. | 2365 | 10 | 30% | 0 090 |  |
| S. 2 | Sheridan Road, South of Lawrence Av | 975 | 25 | 30% | 0.100 |  |
| S. 3 | Surf St , West of Lake View Av..... | 50 | 30 | 50% | 0.160 |  |
| S. 4 | Seventieth St., West of Yates Av.... | 1400 | 5 | 10% | 0.093 |  |
| S 5 | Seventy-third St , West of Railroad Av. | 1200 | 5 | 10% | 0.080 |  |
| T 1 | W. Twenty-sceond, W. of Western Av. | 3400 | 60 | 80% | 0.074 | Occasionally flooded |
| T. 2 | Thirty-fifth St., West of Lake Mich. | 720 | 60 | 50% | 0.104 | Frequently flooded |
| T. 3 | Thorndale Av., West of Lake Mich... | 185 | 10 | 20% | 0.135 | Adequate |
| T. 4 | W. Taylor St , West of River.. .... | 182 | 150 | 90% | 0.290 | Adequate |
| T. 5 | W. Twelfth St., West of River ..... | 148 | 120 | 90% | 0 350 | Adequate |
| V. 1 | Vincennes Av., North of Fifty-first St. | 50 | 30 | 30% | 0.160 | Adequate |
| V. 2 | W. Van Buren St., West of River | 300 | 70 | 90% | 0.180 | Adequate |
| W. 1 | Wentworth Av., North of Calumet R. | 5500 | 5 | 20% | 0.060 | Doubtful, district not developed |
| W. 2 | Western Av., North of North Branch.. | 700 | 5 | 10% | 0.057 | Doubtful, district not developed |
| W. 3 | Wabash Av., South of Garfield Boul.. | 51 | 20 | 30% | 0.310 | Sec. G. 3, G. 4 and F. 5 |
| W. 4 | Webster Av., East of River.. .... | 200 | 50 | 50% | 0 200 | Many complaints |
| W. 5 | Webster Av., East of Halsted St .... | 65 | 60 | 70% | 0.240 | Many complaints |

*Includes 240 acres parks.

## DISCUSSION.

*Mr. L. E. Cooley (by letter)*—The society is indebted to Mr. C. D. Hill for his digest of the results of the sewer system of Chicago. No city in the world has so great a mileage of low grade sewers serving a territory so large and uniformly flat, and which must answer so completely for drainage, both surface and subsoil, as well as for sewerage. As members of the Intercepting Sewer Commission of 1896-1897, Mr. Samuel G. Artingstall and the writer went into this question as fully as the data then available would permit, but the present exhibit is more complete and the study more exhaustive.

The chief characteristic is the low rate of run-off as compared to St. Louis, New York, Baltimore and Washington, in which Mr. Hill notes "that sewers must be built with three times as great a capacity." This led to much discussion and to a difference in the recommendations as to the size of sewers and conduits that should be adopted, and the capacity of pumping stations, all of which make a large difference in the estimates.

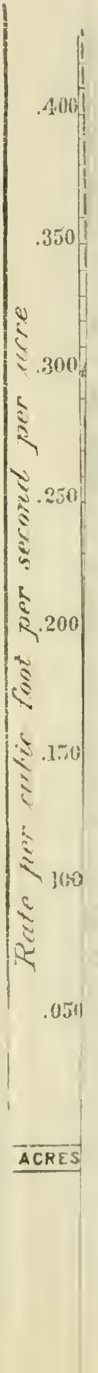
I have been in the habit of approaching these problems from the side of my training and experience in river problems. I have had occasion to give much attention to the various forms of "catchment basin formulæ," of which many have been proposed, designed to give an approximate determination of maximum run-off. From the nature of the problem, such formulæ are designed to determine limits rather than give exact results. There is more reason in this, perhaps, why such formulæ should rest on a rational and experimental basis.

All such formulæ proceed on the assumption that the rate of flood run-off per square mile diminishes with the area of the basin, but there is a wide variation in the expression of what, for want of a better term, I have called the "normal basin ratio." In an investigation which I made of a number of streams with basin areas of 10 to 1,500 square miles, situated under similar climatic and topographic conditions in the state of Missouri, between 1880 and 1884, I found this ratio to be best expressed by the two-thirds power of the area; in other words, the maximum rate of run-off could be expressed by

$$Q = C\, A^{2/3}$$

in which $Q$ is feet per second, $A$ is area per square mile, and $C$ a constant, which is only constant for similar conditions of climate, topography, soil and shape of basin.

The "normal basin ratio" expressed by $A^{2/3}$ I have come to use during the past twenty years as giving on the whole more satisfactory results than any other ratio. The factor C (so-called constant) requires much good judgment in assigning a value. When



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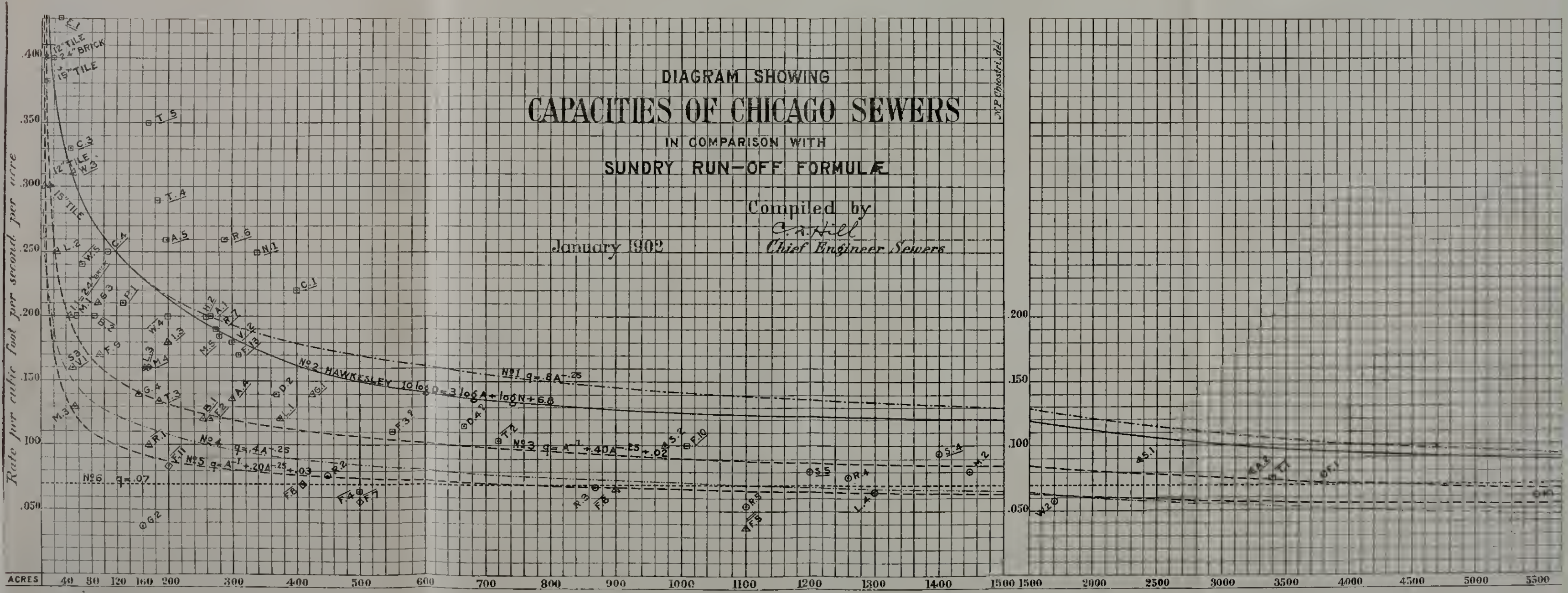

DIAGRAM SHOWING
CAPACITIES OF CHICAGO SEWERS
IN COMPARISON WITH
SUNDRY RUN-OFF FORMULÆ

January 1902

Compiled by
C. A. Hill
*Chief Engineer Sewers*

N.P. Chiostri, del.

some extreme flood measurement has been made of some streams not remote from the territory under consideration, a value can be assigned with much confidence.

It has been noted, however, that the shape of the basin has much to do with the rate of output, this being greatly diminished in long and slender basins as compared with basins whose areas are large in proportion to perimeter. This fact is not accounted for in most formulæ, but is discussed at length and a value proposed by Craig (See Institution of Civil Engineers of several years since). Up to this time, however, I have seen no satisfactory expression for valuing the shape of basin and I have not had occasion to work out a rational expression.

The matter of topography, soil and climate are not likely to be formulated further than to suggest guessing posts for determining the value of C, and the judgment is best guided by actual measurements within the characteristic territorial area.

In a large part of the Upper Mississippi basin C generally has a value of about 180; in other words, $Q = 180 A^{2/3}$. The Desplaines basin above Riverside has a value of about 180, while the Calumet basin above Riverdale seems to have a value of at least 200, and the North Branch above Bowmanville less than 150. The Calumet basin lies in the storm track and its snows melt under the same parallel, while the Desplaines is across the storm track and the snow melting is retarded at the north. The North Branch has a very large proportion of flat drainage and marsh, which impounds flood volumes. When we go into the steep watersheds of the Ohio basin, C may become 250 to 300, or even more, and in tropical countries, as Panama and Nicaragua, it may be double.

If we interpret Mr. Hill's results by this ratio, the limit of maximum run-off would be expressed by $C = 125$, or $Q = 125 A^{2/3}$, taking A in square miles. This gives relatively larger results on the smaller areas than by the formulæ platted. The value of C can be varied according to judgment.

The interesting fact disclosed is that the maximum run-off in sewered districts is less per square mile than the natural rate of run-off in the surrounding watersheds. This would probably not be true of a basin as flat or permeable as the sewered district. Again, the sewer district begins draining relatively early, while much water accumulates on the natural watershed before the train is set up.

The whole subject of the limit in rate of maximum run-off is of great practical importance and has received too little systematic study. The "normal basin ratio" and the effect of shape should be capable of formulation and criteria established for estimating the other elements, so that with the aid of actual observations in characteristic territory it should be feasible to obtain results that will be a safe guide to the engineer in preliminary determinations.

*Mr. J. W. Alvord (by letter)*—The very interesting paper presented to the society by Mr. C. D. Hill puts on record for the first time in tangible shape an extended record of the practical experience of the city of Chicago with theoretical formula, and as such is extremely interesting and valuable.

To those of us who have struggled with this problem in Chicago many years ago with our then meager knowledge, it is perhaps more interesting than it could possibly be to anyone else. As was remarked in the discussion of a previous paper on this subject by the writer, there are a good many things which occur to modify sewer districts not contemplated by the engineer in charge, and in glancing over the list of some of the defective sized sewers in Mr. Hill's list, the writer observes a number of cases which came under his knowledge, which perhaps may be properly explained by him as indicating the difficulties above alluded to. One of these cases is in the Fullerton avenue sewer east of the river. This sewer has a singular engineering history. A sudden change of administration threw out of office the engineering force who had the problem in hand, and installed therein a gentleman who was perhaps more familiar with real estate matters than with the run-off problem. Self confidence was, however, one of his many virtues, and the design and plans were made and assessment levied for a sewer which was about one-fourth of the proper size it should have been to drain the territory assessed. This territory was bounded on the north by Belmont avenue and on the east by Clark street, and the main sewer, instead of running through the center of the district, was located on one of its edges. The original construction was commenced and about one-fourth mile of sewer built before another fortunate change in administration relegated the gentleman to innocuous desuetude, so far as engineering matters were concerned. But the evil that he did unfortunately lived after him. The assessment was already made and largely paid into the treasury and while the one-fourth mile of main sewer already constructed was found to be upon an improper grade and had to be removed, but little could be done by the incoming administration but to enlarge and deepen the plan of this sewer to the greatest extent compatible with the funds in hand, and at the same time plan for another and larger relief sewer on Diversey street in the center of the district assessed. This latter sewer was intended to extend through the entire district, but I believe never reached a point further east than Racine avenue, owing to the difficulties connected with the assessment of territories already once taxed.

Another sewer mentioned by Mr. Hill in his paper is the Robey street sewer north of Roscoe street. This is a singular case where the very best intentions and highest engineering skill has miscarried through the lapse of time and loss of data. The Robey street system was built about 1886, and was designed to drain the village of Ravenswood, then a separate settlement with large stretches of vacant land intervening between it and the city. The writer being at the time City Engineer of Lake View, was charged with the responsibility of this design, and it being a large, important and expensive system, he was allowed by the Board of Trustees to call in as consulting engineer Mr. Benezette Williams of this society. Mr. Williams went over the problem very carefully with the writer, and in view of the large area of unimportant territory between the area to be relieved and its outlet advised that the main sewer on Robey street between Roscoe street and Graceland avenue be made smaller than necessary for the territory which it would ultimately drain, and that in the future an intercepting sewer in Graceland avenue to the North Branch of the Chicago river might relieve the system of its surplus flow as the territory built up and became occupied. Plans embodying this suggestion were made, and the map filed with the then city of Lake View, showing this proposed intercepting sewer. It would seem, however, that through lapse of years and the annexation of Lake View to Chicago with the resulting passage of data into new hands that this entire intercepting project was lost sight of bodily, and later engineering talent provided for sewers on Western avenue independent of all that had been done and without reference to the Robey street district. This whole proceeding clearly illustrates what happens more often than is commonly suspected, that well laid engineering projects and plans are often entirely lost sight of and altered by the shifting and changing of administrations in our American cities.

Another case of this same character will be noted in the list furnished by Mr. Hill on 56th street in Hyde Park. The writer was in 1882 or 1883 or thereabouts, an assistant engineer of the town of Hyde Park, and as such prepared, under instructions from his superior, surveys and plans for the sewer on 56th street from the lake to Cottage Grove avenue of the same size as that at present existing. Just when or how cannot now be recalled, but in some way a subsequent change of administration added bodily to this sewer's territory, after its construction was authorized, the entire area between Cottage Grove avenue and State street, without at the same time increasing the size of the sewer. The writer knows of no hydraulic formula sufficiently imposing and complicated to meet such emergencies as these, and has no doubt that in many of the instances where sewers have proved to be too small in the table as shown, the difficulty has resulted perhaps in some such way as has been above noted. At any rate, in a careful review of all those sewers quoted in Mr. Hill's list of which the writer has positive knowledge, nearly all which are insufficient are so from results which can be traced to extraneous circumstances such as those above given.

So much for the local interest of Mr. Hill's paper. In general, the writer would suggest that he would like to see added to the list some data which would show the character or porosity of the subsoil, and would take occasion to reiterate the same point which he endeavored to bring out in a former discussion of this subject, that for suburban territory the character of the subsoil is very much the most important factor in the designing of storm water drainage. This is shown to some extent in the diagram which Mr. Hill has prepared, especially to one who is familiar with Chicago, but it would be more clearly brought out if it were noted in some way. Of course, this suggestion has nothing whatever to do with territory which is likely to become urban in character. Still, it becomes a question as has been before noted, whether it is desirable to anticipate the future more than twenty or twenty-five years. For instance, the Fullerton avenue sewer above alluded to, may yet be relieved by extending the Diversey street intercepting sewer to Halsted street and perhaps by parallel main on Wrightwood avenue, at least to Ashland. Now the territory, being so fully built up, is far more able and willing to put in these extra sewers than would have been the case twenty years ago when this district was first laid out, not that the Fullerton avenue district as then designed was not a disastrous mistake, but the financial ability of the people to repair such a mistake is much better now than it was twenty years ago. The same may be said of the Robey street sewer. A large population can afford to-day to rebuild the originally proposed interceptor to much better advantage than ever before, although its proper time would have been at the time the Western avenue sewer was designed.

The writer does not know of anything which will add to this discussion at the present time other than an earnest appeal to other cities to put on record in this same way as has been done by Mr. Hill the practical results of their sewer work. Then, and not until then, shall we know something of the run-off problem of the country at large treated in a broad and general way. Any knowledge at the present time is purely local and individual in almost every case.

In addition to his paper Mr. Alvord said:

"In Mr. Cooley's paper he points out that it is singular that the river run-off appeared to be larger and slower in passing off in sewer districts. I think this is due to the fact that in the case of sewers a large portion of the rainfall is absorbed and delivered gradually to the sewer, whereas in the case of the river it is not so marked."

*Mr. Benezette Williams*—I wish to ask Mr. Hill, in reference to the Hawkesley formula, if that is the formula that bears the name of Bazalgette.

*Mr. Hill*—Yes. As I understand it the formula was originated in London, and Mr. Hawkesley and Mr. Bazalgette both used it; one gentleman was superior to the other and the superior gentleman got the credit.

*Mr. Williams*—I would like to say a word in reference to the sewer in Twenty-second street proving inadequate, as mentioned in Mr. Hill's paper. Mr. Clarke was not at all responsible for the Twenty-second street sewer design. I made a study of that district, and my recollection is that my successor in office built it very much smaller than it was at first designed. I think also with Mr. Alvord, that many of the sewers as originally designed have been extended by subsequent officials, covering territories they were not intended to cover. I think this has occurred not only in Hyde Park but in the city proper. Lake View and Hyde Park were for many years separate municipalities, handled by different authorities.

*Mr. Alvord*—I should like to extend to Mr. Hill my thanks for his diagram, coming just as it did when I had to design the drainage of six square miles out at the Chicago Transfer Clearing Company's yards, and in order that the future generations may not lose sight of well-laid plans as they have in the past, I might say that this territory was laid out with a sewer capable of taking the run-off up to a certain character of built up territory, and then intended to be intercepted, so that if the territory is some time in the future annexed to the city of Chicago and some engineer discovers that the main sewer is entirely too small, the records of the Western Society of Engineers may perhaps be searched to advantage.

*Mr. Tratman*—I would like to call attention to the remark on the first page,—"the impossibility of any theoretical formula being applicable to all conditions and all localities."

It is sometimes assumed—especially in the case of the young engineer—that a very important equipment for him is a pocket-book full of formulæ, and that when he strikes a problem all he has to do is to hunt up a collection of formulæ and select one that appplies to that particular case. This is not engineering at all, and I think it should be well borne in mind by the educators of young engineers to teach them that formulæ are not to be used indiscriminately. They must at least understand what principles they are based on and conditions they represent, and I think that is not always done.

On the last page of Mr. Hill's paper, where he says "Instead of using one or more of these formulæ in a rigid manner," I would make that negative statement more positive and say "These formulæ should not be used in a rigid manner," because there is a general impression that if you have a formula, that is all you need.

*Mr. Williams*—I would like to ask Mr. Hill if the general outcome of his paper is not, where this Bazalgette-Hawkesley formula has been followed carefully in such territory as we find in Chicago, that it has generally proved sufficient?

*Mr. Hill*—That is my conclusion from observations here in Chicago where, the formula has been carried out properly, with the exception of the very heart of the city. In this case it is not sufficient.

If I may repeat what I have heard about designing sewers in Chicago years ago,—I have been told that Mr. Clarke was a man who, when he designed a sewer, always cut off a few inches, and possibly that is the cause of the sewers on Thirty-fifth street, North Clark street, or Western avenue, being too small, but the sewers that are as large as the Bazalgette formula would require, have given us very little trouble.

*Mr. Finley*—It seems rather strange to me that the cutting off or adding to of a couple of inches would make any difference.

*Mr. Alvord*—I should like to ask Mr. Hill if he has, in the course of his investigations as to the discharge of Chicago sewers, found it at all practicable to ascertain the quantity flowing through the sewers by marks left within the sewer itself. I have had for some years an idea that possibly something might be determined in that way.

*Mr. Hill*—I have never had the opportunity of making investigations of that kind, but I think it is practicable and it has been done in other cities. Most observations have been based entirely on the high water mark in basements. That is a little uncertain, however, for the reason that the water may stand a foot higher in the basement than in the sewer.

*Mr. Finley*—What conditions do you assume for the inside of a sewer in applying this formula?

*Mr. Hill*—I assume the sewers to be clean and smooth. I use in the formula $N = .013$. I use the same formula in computing the size of a new sewer, so if the assumption is erroneous the error is balanced. I think, as a matter of fact, the coefficient is wrong and that we should use .014. We generally use .013 but sewers ought to be be computed with the coefficient .014.

*Closure, by Mr. C. D. Hill*—Since the paper under discussion was written, there have been a number of severe rainstorms, that have again demonstrated the inadequacy of many of Chicago's sewers, and have severely tested others that were previously above suspicion. To some extent the opinions of the writer have been modified. On the evening of May 24th there was a downpour, aggregating nearly two inches, with a maximum intensity of three inches per hour during a period of fifteen minutes. The result of this storm was that nearly every deep basement in the city was flooded An investigation along the line of the sewer in North Clark street (C. 1 in diagram) showed that the basements near the outlet of the sewer were lower than the crown of the arch and that for a distance of nearly a mile from the mouth (where the capacity of the sewer exceeds the requirements of formula No. 2) the sewer did not flow full, while in the upper portions of the sewer and its laterals (where the capacity of the sewer is but 80 per cent of the requirements of formula No. 2) the water rose far above the crown of the sewers. Moreover, property owners stated that similar floodings of basements have occurred during heavy storms in each of the past few years. A similar condition was found in other sewers in the vicinity, as in Webster avenue (W. 4) from the river to Lincoln avenue.

An investigation of the sewer in West Van Buren street (V. 2) from the river to Western avenue showed that the basements that are lower than the crown of the sewer have been occasionally flooded, giving the inference that during heavy rains the sewers flow nearly or quite full. It will be noted that this sewer is platted on the curve No. 2. These investigations have shown that there are many cases of backwater that are not reported to the city authorities, and to some extent weakens the negative evidence that certain sewers are adequate because no complaints have been made.

The point made by Mr. Cooley, that formula No. 2, when compared to the catchment basin formula for rivers, is equivalent to $125 A^{2/3}$ instead of the usual $150 A^{2/3}$, shows an unexpected approximation when it is considered that formula No. 2 does not pretend to provide for the very heaviest rainfall, and that the former formula is derived from data from areas of less than one square mile, and the latter formula from data from areas of 10 to 1,500 square miles.

As to the question raised by Mr. Alvord in regard to the influence of the porosity of the subsoil. There is no doubt that a sandy subsoil has a material influence upon the rate of runoff in a suburban district. Nevertheless, there is nothing in the data under consideration that shows this. The sewers in 35th, 41st, 45th, 51st and 56th streets are all too small, notwithstanding the fact that the districts drained have a sandy subsoil. Again the sewers in Bryn Mawr, Foster and Granville avenues would probably be sufficiently large, if the subsoil was of clay instead of sand. The sandy districts drained by the sewers in 70th street and 73rd street are not sufficiently developed to enable us to draw any conclusions.

*Mr. Geo. G. Earl, Gen'l Supt., New Orleans, La., (by letter)*—The paper of Mr. C. D. Hill, of your society, "Notes on designing of Chicago Sewers," is an exceedingly valuable record of the experience gained in sewer design for very level areas. In order that the data here given may be intelligently studied to aid in sewer design elsewhere, it would be very useful if Mr. Hill could add to his paper some little statement of the maximum rates of rainfall for short periods and per hour, and possibly of the areas by these maximum rates.*

In New Orleans the Drainage Commission, through its engineers, has designed and constructed many miles of covered and lined canals, and, in order to properly proportion them, automatic self recording rain gauges were erected in several sections of the city and the run-off from old existing canals was measured and checked up against the rainfall records.

This rainfall gauging has been continued from 1894 to present time and its results show that New Orleans has an average annual rainfall of something like 60 inches, a precipitation of 3 inches in a single hour has occurred several times over large areas, and a rate of precipitation for shorter periods and smaller areas of 6 inches per hour is not uncommon.

With an area of over 13,000 acres to drain, and very little natural slope, it is obvious that the problem was a difficult one.

Taking the area where the new drainage system is now in most effective operation, viz: the central business section of the city, we find the following facts: This area is about 11,000 feet long by 5,000 feet wide, and the drainage is from the river back, the long way of the area. The land along the river front is about 15 feet above Gulf level—2,000 feet from the river, where the first line of intercepting and collecting canals catch the drainage, the surface is only seven feet above Gulf level—4,000 feet back from the river the surface is four feet above Gulf level and 11,000 feet back, at the pumping station, it is at Gulf level and the flood slope of the drainage canals at all points is usually only three or four feet below the surface.

The area of this territory is 1,195 acres. There are 29,000 feet of main and intercepting drains with slopes of from 1:2500 to 1:500, the longest line of travel to the pumping station is about 14,000 feet over half of which is at grades of from 1:2500 to 1:1600.

Five hundred and sixty acres of the area is paved and closely built with surface slopes leading to canals of from 1:500 to 1:300. 500 acres is residental area of medium density of population, very little pavement and with surface slopes of from 1:1000 to 1:500 and the balance of the area is sparsely built, unpaved, and has surface slopes of only 1:1000.

The outfall canal for this area as originally designed had a capacity of 1,458 cubic feet per second, or 1.22 cubic feet per acre per second, and this canal as finally built can deliver one cubic foot per second per acre.

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*This subject of precipitation of rain at Chicago, &c., was presented to the Society in a paper by Mr Edward Duryea, Feb. 15, 1899, and discussed by Messrs. Alvord, T T. Johnston, C. D Hill Kuichling, Fuertes, Tutten, McMath, Parmley, H. P. Boardman, Henry and Talbot. Published in JOURNAL Vol. IV. Nos. 1 and 2, pp. 71 and 147.—[ED. JOURNAL]

The local collection systems and means of entrance for drainage into this system of canals is not as yet by any means perfect. The whole area will eventually be much more closely built, completely paved and promptly drained than at present. Despite these facts the flow in the main canal has already upon occasions exceeded five cubic feet per second per acre, or 560 cubic feet per second total flow, pumps of that capacity having worked for at least half an hour without materially lowering the water in the main canal though they were started promptly when the storm commenced and, notwithing the fact that the rainfall in this case did not cover the entire area. The drainage effected was perfect so far as the canals or pumps could reach

It is evident therefore, that the maximum curve of runoff from Mr. Hill's Chicago diagram, though found safe in Chicago, if applied to New Orleans and even multiplied by three, on account of the much larger rainfall would still be greatly inadequate for the particular case in question.

Runoff formulæ depending in part upon the natural slope of the local catchment area, are probably useful and logical, but the extension of such formulæ so as to cover the collection from local drains into main drains is a more doubtful proceeding because in similar channels the velocity of flow in large channels will be much greater for a given slope than in smaller ones, and where the rainfall is such as to render much larger channels necessary the time for the collection of various flows must be less than where smaller flows are collected at similar grades.

For the present the storage capacity of the canals is a considerable factor in prompt drainage, and until there is a pumping capacity sufficient to create the full velocity due to the surface slope of said canals, the real capacity of said canals, as compared with the maximum runoff, cannot be exactly determined. At present, in the case cited, the pumping capacity is only about one-half of the canal capacity, though sufficient to give most effective scouring velocities when flow lines of canal are held to points corresponding with capacity of pumps.

There are so many factors entering into these problems which no formulæ can adequately cover, that a collection of data contributed from the experience of competent observers, in which actual runoffs are given, and the governing conditions clearly stated would be the most useful guide for other work. The development of a formulæ for any given city is possible, after miles of sewers have been constructed and opportunity exists to test them, but the experience and judgment of the engineer is the most important factor usually in the design.

A little later the New Orleans drainage system will afford fine opportunity for the collection of data as to runoffs from flat areas with large rainfalls, and, since this city will shortly construct a separate system of sewerage with an outfall entirely distinct from the drainage, the opportunity to collect data as to the runoff for strictly separate sewers from large or small areas with the flow line velocities increasing with the size of the sewers from two feet to three feet per second, will also exist.

In designing the separate system of sewers it has been assumed that nearly all of the city water supply, which in well built areas will in a year amount to more per acre than rainfall, will reach the separate system of sewers, and that in addition about one-third of the rainfall will also find its way into said sewers as ground or seepage water.

It will be interesting to note how far or near from the mark these assumptions will come, especially to the writer who is largely responsible for the sewerage design.

In assuming rates of runoff for New Orleans the sizes of sewers for small areas have been made with the view of never having to increase or relieve them. As areas increase, however, we have not hesitated to design exactly to our belief as to future runoffs, providing for relief sewers on economical lines, if the necessity for them shall ever arise. In such cases, for areas of over 2,000 acres on the separate system, we have assumed that when the whole area is closely built, water waste will be restricted so that not over 80 gallons per capita will be consumed and that the maximum flows from scattered areas will not all come into the same part of trunk sewers at the same time, but will rather distribute themselves to nearly an average flow.

We have also assumed that with improved drainage and increased paving, ground or seepage water will be greatly decreased.

Where the cost of both water and sewerage in every item depends wholly upon the restriction of wastes, where water from the time it leaves the river as raw water until it reaches it again as sewage has to be pumped three to six times, according to the district in which it is used and where reservoir capacity, coagulant, filter capacity, pump capacity and fuel, as well as the cost of construction of water distribution and sewage collection systems all vary directly with the assumption of amount of water used, it seems logical to suppose that waste restriction will prevail, and when funds are limited and an area of about 13 square miles and nearly 400 miles of street must be covered with water mains and sewers, the necessity goes with the logic.

It seemed better to serve a whole city well now and possibly find trunk sewers too small 30 years hence, than to only serve part for the present with sewers too large for the present efficient operation. In other words the ratio between funds available and present ends which *must* be accomplished, is a factor of vital importance. There is a limit beyond which it should be disregarded, and the proper setting of that limit has always appeared to the writer to be one of the most responsible duties which an engineer is required to meet.

## CLIII.

# ARMOR PROJECTILES AND MILITARY EXPLOSIVES.

By Capt. Charles C. Jamieson, U. S. Military Academy, West Point, N. Y.

*Read July 9, 1902.*

Twenty-five miles from New York the Jersey coast ends abruptly in the highlands of Navasink, an isolated group of hills forming the highest point on the Atlantic coast south of Maine. The coast line then swings sharply to the westward, approaching by a gradual curve the narrows, seven miles from the southern point of Manhattan Island, forming the narrow and splendidly fortified gateway to the world's grandest harbor.

From the highland's, Sandy Hook projects due north about six miles, as if intended by nature for the location of the outer bulwark of our nation's defense at this point. The entire Hook is now controlled by the government, and here we find four departments of its service, the Lighthouse Service, represented by the main beacon erected one hundred and forty years ago while we were still a colony of England, upon what was then the extreme north point of the Hook; today it is more than a mile inland, yet with the north and west beacons still serves to guide the tremenduous commerce of New York in and out through the tortuous channel that passes the very nose of the Hook.

Here also are two stations of the superb Life Saving Service of the United States, made up of splendid men ready at any instant to engage in battle with angry waters to rescue their fellows of all the world. And as if in direct contrast to this careful provision for the safety of men, here too are found the most formidable of our fortifications, where behind well concealed parapets lie, like slumbering monsters, mighty engines of war ready at the proper signal to rise and defend the principles of liberty on which our government is founded.

The firing battery of the proving ground lies to the northeast, with the east half of the Hook for land targets and all the broad Atlantic for fire at greater ranges. Here in the heat of summer and the cold of winter, in all sorts of weather, from early morning until the late hours of evening, a devoted band of officers and men are engaged in "piping times of peace" in preparing for war. Here every gun that goes into the land service receives its test of five proof rounds. Every lot of powder is subjected to ballistic test, and every lot of projectiles must, before acceptance, pass two of its number chosen at random, through the best steel plates. In short, all material, and every proposed device for war receives at the hands of trained experts a thorough test.

This is the Mecca for the man with the flying machine designed to drop explosives upon the unsuspecting hosts of the enemy's army, and of the equally visionary man with the boomerang shell intended upon discharge from the gun to open, and, after sweeping down long rows of the hostile forces, to return and drop at the feet of our gunners to be fired again and again.

Sandy Hook Proving Ground, N. J.

The work in which these men are engaged is not without its danger, and premature explosions in the last ten years have resulted in the death of two officers and upwards of a score of men, while others shattered in mind or body, or groping about in darkness, are dragging out a painful existence, pensioners upon a government's bounty, well earned. Among them, singularly enough, a pale, boyish young man, a stoic when his right arm and hand were blown into shreds by a bursting shell, is Czolgos, a brother of the dastardly assassin of our late beloved President.

The history of the struggle between projectiles and armor which lately ended in the complete victory of the projectile probably for all time, has covered a period of forty years, beginning during our own civil war. The guns in use at that time were low power, smooth bore guns, firing spherical cast iron shot and shell at low velocities, about one-third of that obtained by modern guns. The armor of the period was simple wrought iron, but this was amply sufficient to prevent penetration, yielding only by the racking and breaking of the bolts after continued pounding. With the changes from smooth bore to rifled guns, and from spherical to elongated projectiles of cast iron with chilled points, penetration was complete. It then became necessary to provide a harder surface for the armor, and the result was the compound armor with its steel face welded by special processes to a wrought iron back. When this armor was struck by the projectiles of the period, they were broken into fragments against its face, but, due to the different elasticities of the metals in the armor, the steel tended to separate from the backing, and continued firing, resulted in the breaking of the face, exposing the easily perforated wrought iron back.

Experiments in Italy, and later, in 1878-9, at the United States Naval Proving Ground, demonstrated the superiority of the all steel plate which has passed through various stages of improvement from the first hard plate which yielded by breaking, to the soft one which yielded by punching with improved projectiles, and this in turn through the Tresidder and Harvey processes to the present Krupp plate of superb quality.

The Tresidder process consisted simply in heating one of the faces of the plate to the critical temperature and then cooling it rapidly by forcing jets of ice water against this face. The Harvey process goes a step further. Plates of special composition are buried in sand, or clay, leaving one face exposed. The exposed face is covered with pulverized charcoal, weighted with fire brick, and the whole plate raised to a cherry-red color, at which temperature it is kept from four to fifteen days, depending on the thickness of the plate. This process increases the percentage of carbon on the face of the plate to a considerable depth. The plate when with-

CARNEGIE-KRUPP FACE HARDENED
16' X 7½ X 11½
MIDVALE A.P. SHOT Nº 834 EXPLOSIVE D.

drawn from the furnace is cooled by the Tresidder process, giving an extremely hard face with a tough back, thus increasing the efficiency of the plate about twenty per cent. The Krupp process is practically an extension of the Harvey both in treatment and composition, and has so improved upon it that the six inch Krupp is nearly the equivalent of an eight inch Harvey plate.

The change from wrought iron to steel for armor, necessarily led to the abandonment of cast iron shot for those of steel, and these, later, were made of special composition and subject to treatment under various formulæ.

Modern sea-coast projectiles are divided into shot, and shell, for all guns except the mortar, which uses shell only. The word "shot" originally meant a solid projectile, but in the chilled cast iron and the forged steel shot it was found that a cavity gave a stronger projectile by removing internal strains, and facilitating treatment. The primary idea was to use the shot without explosive to attack the heavy armor, following with shells against the broken plates and lighter armor. The later explosives developed, however, are sufficiently powerful to break these shot into many fragments, and they are accordingly used as shells.

The conditions of acceptance of projectiles at present are, that two from a lot shall pass through the prescribed thickness of plate without cracking or material deformation, the thickness of the plate depending upon the size of the gun, those for the twelve inch being a seven-inch nickel steel plate with a striking velocity of 900 feet per second for armor-piercing shell, and a twelve inch face-hardened plate with a striking velocity of 1475 feet per second for shot. These velocities are just sufficient to insure penetration, and make the test the severest possible against this thickness of plate, as a shot which will fail at these low velocities will penetrate perfectly well without breaking if fired at a higher velocity. Mortars are short guns designed for firing at angles from thirty-five to sixty degrees elevation, and are intended for use against the decks of ships. The armored decks of ships, which lie practically below the water line, are four and a half inches thick, and the requirement for the test of twelve inch deck-piercing shell is, accordingly, that they shall penetrate this thickness of plate at an angle of impact of sixty degrees, about that which may be expected in service. In this case the shell does not pass through in the line of impact, but swings up normal to the surface, with the result that failure most often occurs by breaking about midway back.

Simple or soft nickel steel plates may be attacked by uncapped projectiles, though against these the later form of cap-projectiles are more efficient. When penetration occurs in this plate the face of the plate rolls back around the hole until it somewhat resembles the petals of a flower; the shot, when recovered, is to the eye apparently perfect, but caliper measurements show that the shot has shortened with a corresponding increase in diameter.

The points of uncapped projectiles were often broken by the face-hardened plates, thus preventing penetration. This difficulty has been overcome by covering them with soft steel caps which are held in position by a lip forced into a groove formed around the projectile about three inches back of the point; this cap supports and assists the point of the projectile, but more particularly, upon impact it causes the whole face of the plate to dish, so that the plate is just ready to yield by the time the point of the projectile has passed through the cap. In hardened plates the skin formed by special treatment, flakes off around the hole, causing dangerous flying fragments which frequently show a fine amorphous structure, similar to the beautiful effects of frosted silver.

But, though your projectile will penetrate the plate, it is relatively harmless unless detonated by a proper explosive for a shell filler. Until within a few years black powder was the explosive universally used, both in gun and projectile. With the change from low to high power guns, and from iron to forged steel projectiles, this powder failed as a shell filler, because too sensitive to shock and too weak to break the shell into sufficient fragments, failing to rupture the armor piercing shot under the most favorable conditions.

The discovery and development of a proper explosive has been a tremendous and difficult problem, which also involved the parallel development of a proper detonating fuse, in itself a problem presenting tremendous obstacles.

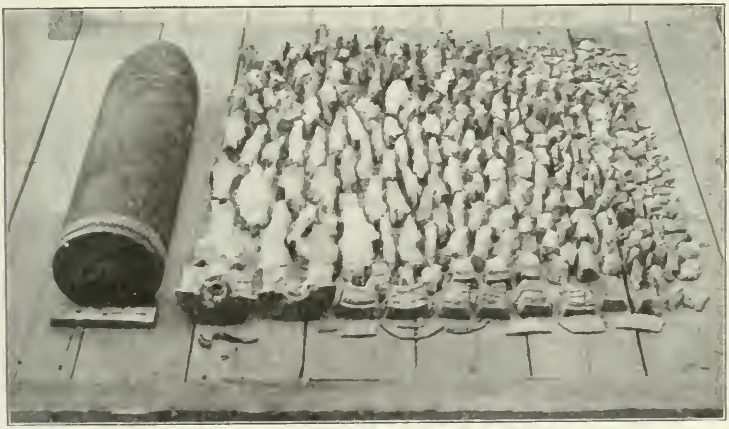
Two systems of attack against armor has been proposed; first, the exterior detonation of large masses of high explosives in thin walled shells of various types; second, the penetration of the plate by the projectile with detonation of the explosive in rear. This last has been the object sought by the Ordnance Department through fourteen years of continous experimentation. In 1888 General Abbott as a member of a special board began his experiments on the strength of explosives by detonating given quantities in earth, and measuring the craters thus formed. The resulting formulæ are still accepted as standard. The work at first was necessarily slow as the field was new, and methods and implements, had both to be devised.

During this period the whole field of explosives has been covered and not a few new ones have resulted from the search for one that would satisfy the difficult and contradictory conditions. Twenty-five approximately passed through the preliminary tests and were subjected to the firing tests. Among the earlier ones, was amonite in 1892, now interesting particularly because of its composition, which is almost identical with one recently presented and exhaustively tested under the name of Thorite; Emensite, in 1895, seemed so promising that a fifteen inch smooth bore gun was rifled and special projectiles made for its test. The projectiles weighed loaded 1,600 pounds and contained 500 pounds of Emensite. The gun was totally destroyed upon firing, and Emensite was adversely recommended. Experiment with fine-grained smokeless powder as a shell filler gave similar results in the twelve inch mortar, opening it up until the rear end back of the point of rupture looked like an immense tulip, and one of the steel hoops breaking at one point, was straightened into a simple steel billet. Similar results were obtained from the same explosive in the seven inch howitzer, the breech of the piece being completely destroyed, while the block lodged between an eight inch rifle and its carriage.

Gun-cotton as one of the most stable and best known explosives, was thoroughly developed, as by varying its form and the percentage of contained moisture, its sensitiveness could be largely controlled. But if enough water were used to render it sufficiently insensitive to shock against the plate it could not be completely detonated by the fuse. As the best of the earlier explosives, however, it was officially adopted, pending further experiments.

In 1898 the requirements for a satisfactory explosive were formulated by the Department, and are as follows:

1. The explosive must be chemically stable, and not subject to deterioration in store.



Gun Cotton Fragmentation, Twelve Inch A. P. Shell.

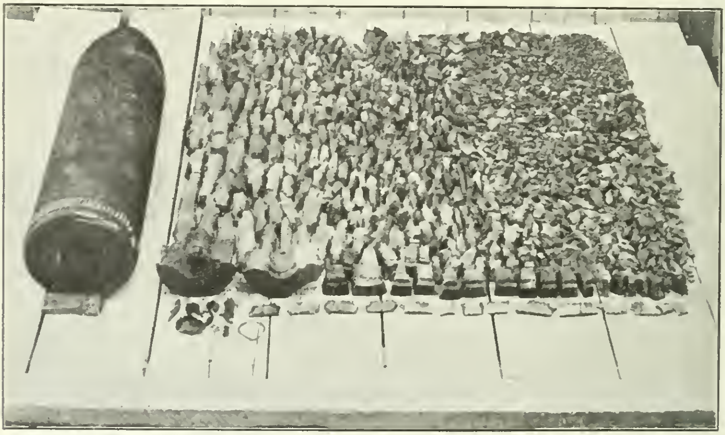
2. It must be of convenient form for loading into shells, and the loading must not be attended by special danger.

3. It must be sufficiently insensitive to withstand the shock of discharge from the gun, and the tremenduously greater shock of impact against the plate of the prescribed thickness, for example, a twelve inch plate, when fired in a twelve inch armor piercing shot.

4. Finally, it must be completely detonated after passing through the plate, by the service detonating fuse.

The tests for chemical stability and sensitiveness are now made in the labratory at Frankfort arsenal, Philadelphia, where the energy required to detonate a given quantity of explosive under constant conditions is measured in foot pounds.

Another test is for fragmentation, made by putting the shot in sand or the explosive chamber, and detonating the fuse electrically. This gives a comparison of the relative force of the explosives, and singularly enough the two most powerful are also the most insensitive to shock. The principal explosives in order of power as developed by fragmentation tests are black gun powder, Thorite, rendrock, gun cotton, Maximite, and Explosive D. The number of fragments varying from four or five in the black powder to as many as seven thousand for Maximite when detonated in the twelve inch armor piercing shell.



Fragmentation of Twelve Inch A. P. Shell by Maximite.

A third test to which explosives are subjected, is that of firing unfused shells filled with the explosive, against plates of varying thickness to determine the maximum plate that can be penetrated without detonation due to shock, the minimum requirement being a seven inch plate for a twelve inch armor piercing shell. Of all explosives tested two only, Maximite and Explosive D, have successfully passed this requirement, and these have been successfully fired through twelve inch face-hardened plates when used in the twelve inch armor piercing shot.

The plates in these tests were backed with timbers but without sand, to determine the results under the most difficult conditions. The projectiles penetrated the plates, exploding in the plates and absolutely destroyed the entire structures. The explosives were accordingly adopted for use in the army sea-coast rifles.

Various devices have been designed for safely firing sensitive explosives from high power guns. The Isham diaphragm shell is perhaps the best of these. The shell is cast steel, with a spindle running from point to base and diaphragms cast at intervals of five inches, which with the spindle and walls divide the interior cavity into ten rings. The pressure on the base of a long column of explosive necessary to produce the acceleration required in a high power gun, frequently produces heat enough to detonate the explosive. The idea of the diaphragms in the Isham shell is to shorten the column of explosive and thus reduce the pressure below the danger point. This was successfully accomplished, but there are many objections to the method. Any imperfection in the casting may allow entrance of gas from the gun. The method of loading the ten compartments through holes in the exterior walls of the shell is necessarily laborious, and any portion of the exceedingly sensitive explosive used remaining in the threads of the filling-holes might cause detonation, and, finally, the effects produced by this shell upon the plate were not equal to those produced by the service projectile without explosive.

Competitive experiments to determine the comparative effects were made in 1899. A twelve-inch Harveyized plate was so placed that it made an angle of forty-five degrees with the axis of the gun, the most favorable position for a shell of this class, for upon impact the shell detonates, and that half towards the plate is forced against it by the detonation while in normal impact its energy would be dissipated parallel to the face of the plate. The shell in this test with its charge of 129½ pounds of explosive gelatine was fired with a striking velocity of eighteen hundred feet per second. The plate weighed eighteen thousand pounds, so that the striking energy of the projectile weighing one thousand pounds was sufficient to give the plate a velocity of one hundred feet per second. The shell upon impact detonated, while the rear end was in front of the right half of the plate; the plate, as a result, was rotated round the middle support of the back, and sliding along on its edge fell upon its face seventeen feet from its original position. The plate itself was recovered, but slightly injured, being dished about two inches in the middle and showing incipient cracks along its right edge. A second shell containing 130 pounds of explosive gelatine was fastened against the uninjured portion of the plate and detonated by the service fuse. Upon recovery after this test the plate was found to be still intact and capable of very considerable resistance.

For the test of the service projectile all conditions were, as far as possible, identical, except that a twelve inch armor piercing shot capped, but without explosive, replaced the Isham shell. Up to this time there was no record of impact against face-hardened plate at angles greater than 21 degrees from the normal. The result was extraordinary: The projectile bit into the plate to a depth of eight inches, and carrying away the supports, moved the plate bodily back into the sand two feet, at the same time breaking it in halves; the projectile itself was broken into fragments, one remaining upon one of the pieces of the plate. Thus the destructive effect of the service shot without explosive was greater than that of the Isham shell fired under exceedingly favorable conditions.

The last and most interesting experiments with devices of this class were those made with Gathmann shell.

"The history of these experiments is most interesting, because

"1. The Gathmann Company clearly defined what their shells and gun would do;

"2. The Navy and War Department asserted that these results could not be produced;

"3. Congress appropriated ample funds for the experiment;

"4. Many tests and experiments were made, all sustaining the position of the experts, and the final tests were made under conditions absolutely guaranteeing completeness and fairness;

"5. The results absolutely demonstrated two facts, first, that the Gathmann gun and projectile are practically valueless as instruments of war; second, that the regular army twelve inch gun with its armor piercing projectile charged with the latest army explosive, is the most destructive weapon ever devised."

These are the strong words of the Hon. R. W. Taylor on the floor of the House of Representatives on April 19, 1902.

The first experiments with this system were at the Naval Proving Ground under an appropriation of $50,000 made by Congress in 1896. The projectiles were tested by firing from an eight inch muzzle loading rifle, from an experimental twelve inch rifle, and by explosions against armor plates.

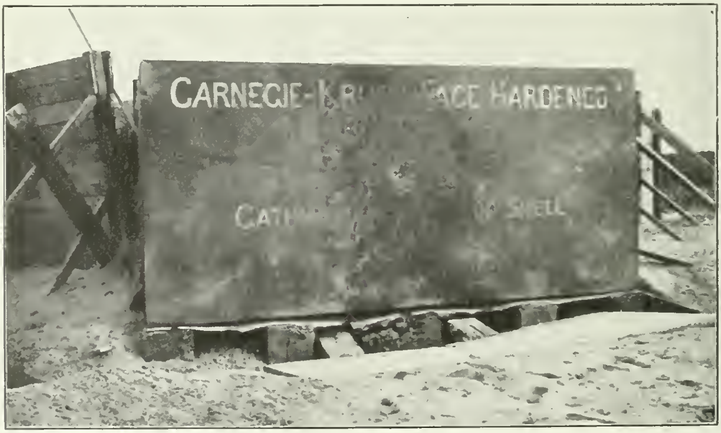
In the first firings from the twelve inch rifle, the shells were filled with water, and three out of four broke up in the gun. The shells were then strengthened and a round was fired with a shell loaded with 307 pounds of gun cotton and 35 grains of fulminate in the fuse. This shell exploded in the gun completely destroying it. Three subsequent rounds were fired in the eight inch rifle with shells charged and fused, but in none of these was the cotton detonated. The explosion against plates produced no material damage, and the report was against the system.

In 1898 an allotment of $20,000 was made by the then Secretary of War, from the war emergency fund for experiments, at the Army Proving Ground. The type of projectile presented was one having the body of less diameter than the bore of the gun, with an expansion band in front; the base which carried the fuse was a sliding piston with three radial lugs for centering it, the theory being that the gases would pass round the body of the shell to the expansion band, and the piston base acting on the saturated gun cotton would result in an equal interior pressure so the walls could be made very thin, thus carrying a large charge of explosive. Four shells of this type loaded with gun cotton were fired against a nickel steel plate ten inches thick, four feet wide and eight feet long. After the fourth shot the plate was found broken in two fragments,—a result that could have been obtained by a single round from an eight inch service rifle using an armor piercing shot with no explosive. As result of these and subsequent experiments this type of shell was abandoned and a new type devised. The second type differs but slightly from the service projectile. The front bearing portion of the shell is placed at the center of gravity. From this point forward, by a gradual taper, the diameter is reduced from twelve to ten inches, ending in the ordinary ogive. The claim advanced was that this form of projectile greatly reduced the resistance of the air and thus made it possible to use thinner walls for the shell with increased charge of explosive.

Congress made two appropriations for the test of this type of shell; first, one of $75,000 to build an eighteen inch gun, and then one of $55,000 for the construction of targets, thus bringing the total expenditure on the Gathmann system up to the very respectable sum of $200,000. The gun built under this appropriation was a low power gun of large calibre, differing in no essential particular from the service gun, except in the diminished thickness of walls. The projectile for this gun of the second type described, weighed loaded, about 1,840 pounds; the service projectile for a gun of this calibre would weigh 4,400 pounds, with the result that the Gathmann projectile could be given high initial velocities with low pressures, but the velocity would fall off very rapidly as the range increased.

The targets used were similar in all respects, and actually represented a section of the latest type of battle-ship, but the structures themselves lacked the support of the adjacent armor plates and of the skin, frames, beams and decks that go to make the whole structure of a ship. It was concluded, however, that the targets were sufficient to make conclusive deductions as to the effect upon a battle-ship.

Round 1: A Gathmann projectile weighing 1834 pounds, including 497 pounds of wet gun cotton, struck the center of the plate with a velocity of 1650 feet per second, corresponding to a range of 2,700 yards. The energy of impact due to the mass of the projectile, was 34,610 foot tons; the gun cotton detonated on striking the plate; the plate was dished in the center one and one-half inches in the major axis and one-half inch in the minor axis and slightly flaked at the point of impact, otherwise it was uninjured. The backing and the frames behind the backing were uninjured, except for the shearing of a few rivets. Had this shot struck the belt armor of a battle-ship, it would not have endangered the vessel.

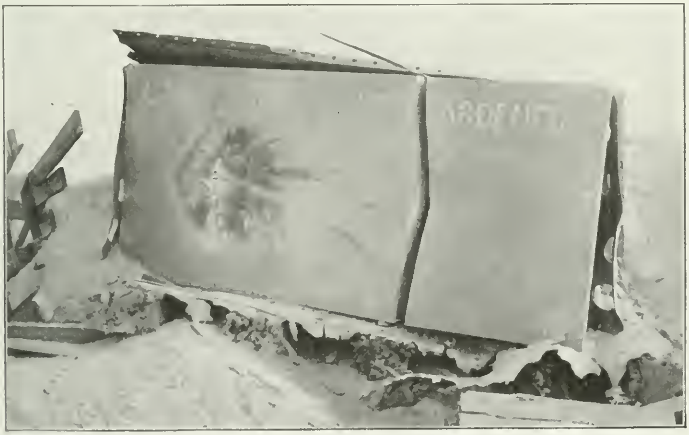


Twelve Inch Plate After First Gathmann Shot.

Round 2: A Gathmann projectile, weighing 1839 pounds, including 507 pounds of wet gun cotton, struck the right center of the plate with the same velocity and energy as before, detonating on impact. The effects on the plate and structure were similar to those of the first shot. The right hand edge was moved to the rear, and the whole structure moved thirteen inches to the right, some of the frames were slightly buckled.

It being evident that neither of these rounds would so have injured a ship as to endanger its buoyancy, it was decided to fire a third shot at point blank range in order to determine if it were possible to inflict any damage whatever upon the plate by this system of attack.

Round 3: A Gathmann projectile, weighing 1840 pounds, including a charge of 514 pounds of wet gun cotton, struck the left center of the plate with a velocity of 1970 feet per second, corresponding to point blank range. The striking energy was 49,500 foot tons. As a result of this shot there was a vertical through crack eight feet distant from the point of impact extending through a row of bolt holes and through the place struck by the preceding round. In other respects the effect on the plate was in former rounds, the backing and the skin plates behind it were slightly displaced, the bottom left hand side of the plate was shoved back four feet and the whole structure rotated to the left about thirty degrees. It is evident that had this shot struck the belt armor of a battle-ship it would have resulted in no injury to the interior mechanism, its armament, or its personel, and would not have seriously menaced its buoyancy.

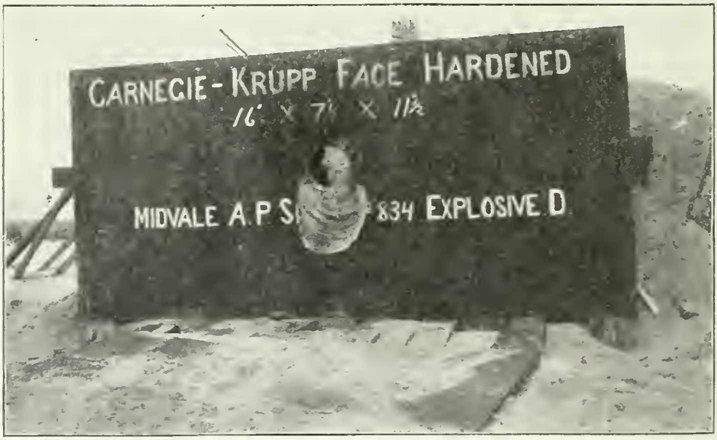


Twelve Inch Plate After Third Gathmann Shot.

TEST OF THE TWELVE INCH SERVICE RIFLE.

Round 1: A twelve inch armor piercing shot weighing 1001 pounds and 7 ounces, including 19 pounds and 7 ounces of Explosive D., struck the center of the target with a velocity of 1800 feet, corresponding to a range of 4400 yards, with 22,500 foot tons striking energy. This shot penetrated the plate and detonated in rear. The backing, the skin plate, the frames, and cofferdam plates were completely demolished in line of impact; the crater formed in the sand butt in rear of the structure measured 15 by 6½ feet. Pieces of the plate and projectile passed through the structure, through the butt, and were recovered from 150 to 200 feet in rear. It is evident that this shot would have seriously affected the structure and armament of a ship.

Round 2: A twelve inch armor piercing shot weighing 1006 pounds with twenty-three pounds of Maximite, struck the right center with the same velocity and energy as before, detonating in the plate and completely wrecking the right hand portion ; it demolished the frames behind the armor and the plates of the coffer-dam.

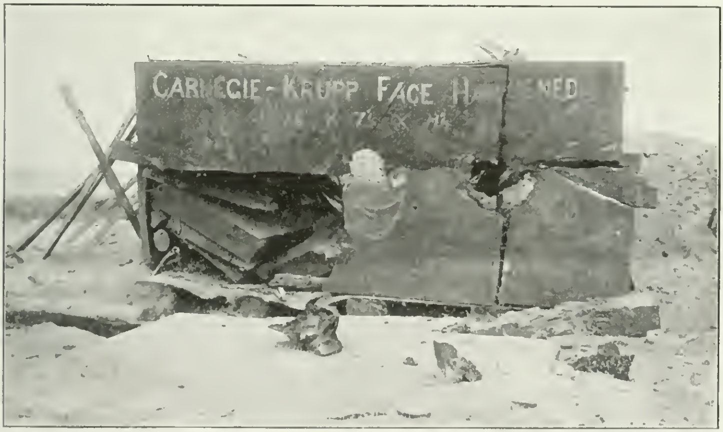


Twelve Inch Plate After First Service Shot.

Rear View of Twelve Inch Plate After Second Service Shot.

Round 3: A twelve inch armor piercing shell weighing 1,045 pounds, including sixty pounds of Explosive D., struck the lower left hand corner with a velocity of 2,073 feet per second, corresponding to a range of 1,880 yards; the energy was 31,100 foot tons. The shell penetrated and detonated in the plate; the plate was completely wrecked, and the backing, frames, beams, and cofferdam plates of the structure demolished. An opening four feet wide by eight feet long was made through the plate; one large fragment about two by two and a half feet was hurled through the target and through the butt, being recovered 135 feet in the rear of it.

The Act of Congress required that at least ten shot should be fired at the structure from the army rifle, but the annihilation of the structure by three shots made it impracticable to comply with the mandate. It may be said in this connection that the destructive effect of the twelve inch armor rifle surpasses anything hitherto obtained from any gun so far as records show.



Front View of Twelve Inch Plate After Third Service Shot.

The report of the Board conducting these experiments bore this indorsement from the Chief of Ordnance:

"Respectfully submitted to the Honorable, the Secretary of War: As this test has afforded the first occasion for demonstration to others than the officers of the Ordnance Department who have been concerned in their development, of the power of the explosives used with the twelve inch army rifle, it appears pertinent to invite attention to the cardinal points of the achievement, namely: The development of an explosive sufficiently insensitive to be fired with safety from high power guns with full charges.

"Sufficiently insensitive to withstand the shock of impact against heavy armor plates.

"Sufficiently powerful to produce as great a shattering effect as desired.

"The development of a detonating fuse which is capable of being fired with safety from high power guns with full charges, which is sufficiently powerful to realize the full force of the explosive, which, set in action by the impact of the projectile, produces detonation after sufficient delay to insure penetration and the greatest destructive effect both upon and behind the plate."

These formal words state briefly the solution of this problem as it is presented to the people of the United States, by their public servants, the officers of the Army Ordnance Department.

NOTE.—In the Proceedings of the Institution of Mechanical Engineers of London, England, for 1901, is an interesting paper on "Naval Ordnance," by Lieut. A. Trevor Dawson, of London, England. This paper, well illustrated, shows types of naval ordnance, describes the construction of the guns of various types and sizes, breech-mechanism, etc., mountings, motive power for operating the guns, etc. Some U. S. guns are described in detail. The velocities of projectiles from modern guns are also treated.

Taken altogether, this paper is a valuable one in relation to the paper by Capt. Jamieson.

To those interested in this subject the reports from the Chief of Ordnance, War Department, U. S., in the library of the Western Society of Engineers, gives much matter in detail worthy of careful study.—ED. JOURNAL.

## CLIV.

# ENGINEERING IN ARGENTINA.

By E. L. Corthell, M. W. S. E.

*Presented Sept. 3, 1902.*

There could easily be crowded into a few pages a mass of figures covering the physical conditions, growth, industrial features, the population and habits and customs of the inhabitants of the Argentine Republic; but as we do not read encyclopedias with any special interest, let me clothe the naked facts with some personality and and make them as they are when associated with humanity in its various phases of life.

The backbone of the two continents is continuous, starting from Alaska and stopped only by the Straits of Magellan. This extensive and generally lofty range of rocky Cordillera is the spinal column of the giant whose body is alive with the elements of humanity which live upon it. Towards its lower extremity this backbone is straight and edges toward the Pacific Ocean, leaving only a narrow margin of land about 140 miles in width.

Argentina, with which we have to do, has some interesting similarities to the United States, if we exclude Alaska, which I will speak of, to give by comparison a better idea of the size of the Argentine Republic. It extends from 22 degrees South latitude to 55 degrees, or 33 degrees long. The United States extends from about 25 degrees North to 48 degrees, or 23 degrees long, so that Argentina is nearly fifty per cent the greater, North and South. The length of Argentina is nearly 2,300 miles or about two and one-half times the distance from Chicago to New Orleans "as the crow flies" and the width of the country averages about five hundred miles. In longitude it extends from 56 degrees west of Greenwich to 76 degrees, or 20 degrees wide. while the United States in its greatest stretch across the northern continent extends from 68 degrees to 125 degrees, a width of 57 degrees, or more than two and one-half times that of Argentina. The area of the United States is three million square miles, as compared to one million two hundred and twelve thousand of Argentina, again more than two and one-half times as great. To further locate us, I will say that my desk where I am now writing is as far south of the equator as Wilmington, N. C., is north of it, and a line extended towards the North Pole would just strike the most westerly point of Newfoundland and cut off to the east ¼ degree of Labrador.

As might be expected of a country that lies flat along the ocean and only assumes to climb to the height of the Andes where it approaches them, it is almost tropical in its northern areas and almost Antarctic in its southern, and rising from the level of the sea, to the mountain peaks which are among the highest in the world, must have a climate varied in the extreme and yet it is not extreme except in high elevations and in the extreme south in Patagonia. I have

Valley of Horcones and Mt. Aconcagua, 22,322 feet High.

seen at a distance of about one hundred miles, the snow capped peaks of Aconcagua, 22,322 feet, and the Tupungato, 22,015 feet, above the sea level. The highest in the United States is Mt. McKinley in Alaska, 20,460 feet. In the United States proper, the highest is Mt. Whitney in California, 14,898 feet.

If we consider the two principal forces that go to make climate—temperature and rain—we find as much variety going east and west on the same parallel of latitude as going north and south on the same meridian. For instance, along the narrow strip of 1 ½ degrees in width which lies in the tropics north of the Tropic of Capicorn we find a regular decrease in temperature going west from 73 ½ degrees to below 57 degrees, and the rainfall diminishes from 63 inches to less than 2 inches, and this along a path five hundred miles long. The tropical vegetation in the east changes to arid table lands in the west and then almost instantly up the steep slopes where nothing grows but lichens.

Along the parallel of 30 degrees the same marked change, but different temperatures exist. Along this width of seven hundred and twenty miles, five hundred and forty have the same temperature and the rainfall decreases from 47 inches to 4 inches. Still further south where the country is only two hundred and forty miles wide, there is very little change going west, the isothermic lines of about 57 degrees extending straight across the country to the very feet of the Andes, and the rainfall is about 12 inches. In the extreme south at 55 degrees, the climate is very severe. The temperature of Tierra del Fuego and its adjacent islands varies from 46½ degrees in the summer to 35½ degrees in the winter. Snow falls every month in the year and the total rainfall, that is rain, snow and hail, is about 55 inches.

Even after a residence of over a year in Buenos Aires we cannot make it right that summer is in January, autumn in April, winter in July, and spring in October. Nor can we make it seem natural to have the sun shine into our houses from the north, and the north wind warm, and the south wind cold. Instead of Texas northers and Dakota's blizzard's from the north and northwest, we have here the cold pamperos from the southwest. But hardest of all to bear is the loss of the North Star which all our life has been our symbol of steadfastness and our example of stability. But we look south to the Southern Cross and console ourselves that still the movements of the planets and the world are the same everywhere in our universe.

Plaza Libertad, Buenos Aires, S. A.

Here, in Buenos Aires, the capital, the rainfall is varied. It averages 35½ inches per annum, but it varies from 22 inches to 53 inches although in 1890 there fell 73 inches. As to heat in this city, it is very rarely that it becomes oppressive and throughout the year the temperature is remarkably uniform compared with almost any part of the United States. In 1899 the mean in June and July, the coldest months, was 54 degrees, and in January and

February, the hottest months, 76 degrees, the average mean for the twelve months being 66 degrees.

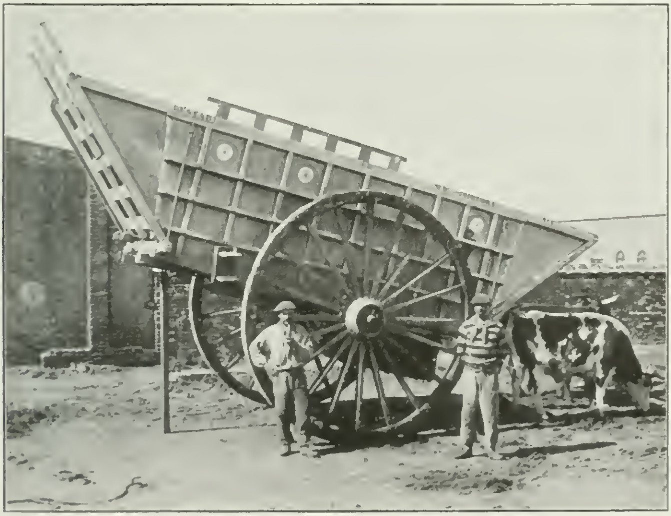
To the geologist there are exceedingly interesting features worthy of outlining in order to enlarge the boundaries of our knowledge and bring us to the final and most interesting conditions, the vast river system comprising rivers larger than any in the United States and next to the greatest in the world.

One of the most interesting and unusual features of the country is the great Pampean plains. These Pampas seem almost endless and remind one of the vast western plains of the United States, but here they are almost unbroken by even small water courses, and there are not sufficient undulations to lead the railroad engineer to deviate his line for them. In fact, there is in this country on the line of the Pacific railway the longest straight line in the world of one hundred and eighty-six miles.

These great plains are of comparatively recent formation geologically speaking. There is abundant evidence to prove the existence of an ancient Pampean sea and of an immense lake connecting with it very much as the Mediterranean and Black Seas are situated and connected. During this period there was deposited over the submerged areas a layer of Pampean mud 50 feet or more in thickness and covering an area of 400,000 square miles. An idea can be obtained of this remarkable body of water when we compare it with the combined area of the five great lakes of the United States, which is less than 100,000 square miles, about one-quarter of the area of the Pampean Sea. Without going into details of the process or the history of the formation, it may be stated that the bed of these seas uprose in the general elevation of the Andes and their slopes, and that now one of the greatest agricultural areas and one of the richest, comprises a large part of the habitable country of Argentina.

The former drainage area of the La Plata southward was far more extended then than now. Its northern limit was at about 10 degrees south latitude and nearly all the waters which is now from the Maderia River, the principal affluent, flowed south into this Pampean sea which extended north over the plains of the present Argentine Republic to about 19 degrees south latitude. This river in its present northward direction has a mean flow of about 305,000 cubic feet per second, larger than the St. Lawrence. By the lifting of the mountains and that part of the continent adjacent, the flow of this great river was turned in an opposite direction. These great changes in the drainage of the country may remind some of those present of somewhat similar changes not far from Chicago, and this marked and interesting coincidence is fully given, in the writer's paper on the Mississippi Delta familiar to many members of this Society.

Coursing through these superelevated plains of Argentina is one of the greatest river systems of the world. Two great rivers discharging into the third, the Parana and Uruguay into the La Plata, the latter being not only a fresh water river but an estuary of the sea. Can you imagine a river from thirty to sixty miles wide? The watershed of this system is about 1,200,000 square miles in area. The Parana has nearly 1,000,000 of these. Its mean annual discharge at Rosario, about 225 miles above Buenos Aires, reaches 163 cubic miles, nearly 900,000,000,000 cubic yards, an amount difficult for the mind to grasp. In the period from 1881 to 1883 the mean annual discharge was 230 cubic miles or forty-five per cent greater than that of the Mississippi in the same period, double the mean discharge of the Ganges, three times that of the St. Lawrence, four times that of the Danube, and five times that of the Nile. We have records of 374 cubic miles in one year.



A Cart of the Country.

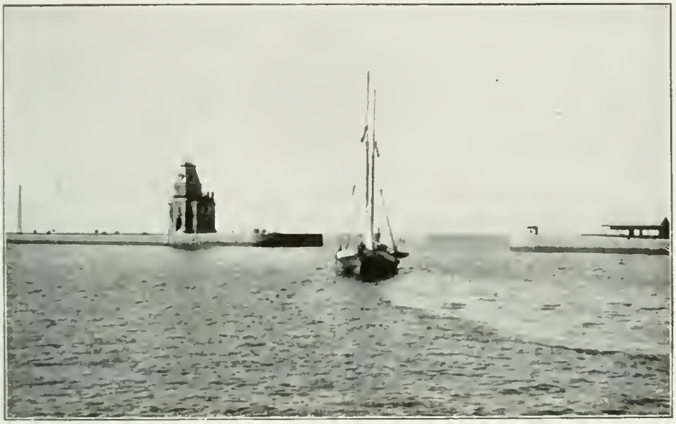
With lands so level and so rich, with such magnificent waterways, is it strange that it is "par excellence" the land of the farmer and the cattlebreeder? Of wonderful fertility, lying on the sea with a coast line in one province alone of 1,000 miles of river and sea, a climate mild all the year, subtropical in many parts, no snow, no ice and really no cold weather, it is the "El Dorado" of the agriculturist.

In 1885 the National Government began the construction of very large docks at Buenos Aires, hitherto all business has been done from the anchorage about twelve miles from the city, this intervening space being a great mud bar, the water from a depth of 25 feet gradually shoaling to the water line at the city. This was so flat that it was often necessary to transfer the passengers and goods from the lighters, with which they had come thus far from the vessels, to small boats and great wheeled carts that went out a long distance in the water to meet the lighter. The new docks are very extensive and lie along the immediate front of the city and connected with it. They were designed by the well-known English firm of engineers, Hawkshaw & Hayter, and the construction carried out under the supervision of Mr. James Dobson the resident engineer and later a partner in the firm. The concessionaire was an Argentine citizen, Mr. Madero. The contractors were the experienced English firm of Walker & Company. These men all deserve the highest credit for carrying through, under the great financial difficulties above mentioned, a great public work costing $38,000,000 gold.

Dock No. 4. Harbor of Buenos Aires, S. A.

In order to reach the docks from the sea a channel had to be excavated in the mud foreshore from the anchorage. This channel (the north one) is at low tide 21 feet deep and 330 feet wide and about 5½ miles long from its intersection with a channel, which already existed by previous dredging, from the other end of the port at the mouth of a small sluggish stream called the Riachuelo, in which channel there generally was about 19 feet of water at low water. The tide of two or three feet depending largely upon the direction and force of the wind and very uncertain, permits vessels drawing about 23½ feet to enter the port at the north channel. The new port was connected with the older port and now both channels are being used and the depths in them are about as mentioned above 21 and 19 feet.

The Government has recently decreed the extension of the North channel straight out to the anchorage and later its deepening to 22 feet. In the meantime the navigation uses a crooked channel, beyond the intersection, which had been partly dredged curving round from the South channel to the anchorage. The depth of the water in the entrance basin is 21 feet, but in the four great docks is 23 feet, with tidal gates so that vessels at low tide may float by the retention of the water by means of these gates. The works are built in the most substantial manner with masonry walls founded on what is called "tosca," the hard substratum that is found in this part of the country, nearly the consistency of rock.



North Entrance to Harbor. Buenos Aires, S. A.

The four docks are from 620 to 750 yards long and are all 170 yards wide, connected by passways from 22 to 27 yards wide, over which by hydraulic turning bridges the foot, vehicular and rail traffic passes. A sea wall in front protects the entire port. On the city side are three and four story brick warehouses. Sheds, cattle yards, railroad tracks, hydraulic cranes and capstans and other important appurtenances give the port all the modern facilities for handling cargo. When the docks were open at the southern end in 1889, the register tonnage of vessels arriving and departing was about 4,500,000; in 1899, ten years later, it was 9,300,000 or more than 100 per cent increase. There are only twelve ports in the world of greater tonnage, and none of these show such phenomenal growth.

One of the principal ports of the country is Rosario, about 225 miles by the Parana River and 200 miles by rail from Buenos Aires.

It is the export of cereals raised in the State of Santa Fe which lies back of it, one of the most productive of the country. Ocean navigation reaches it and for that matter to Colastine, the port of the city of Santa Fe, the capital of the province. The registered tonnage of the port of Rosario in 1899 was 3,000,000 of which more than 2,000,000 were over sea-going vessels. The merchandise entered and cleared was about 1,650,000 tons. Sixty-seven per cent of the exportation was wheat. In the busy months there are often over thirty vessels along the wharves and the barranca where the wheat is loaded in bags, sliding down from the cliff 20 feet above the vessel in what are called canaletas.

Marine Railway. Department of Public Works, Buenos Aires, S. A.

The national government is preparing to make a great port of Rosario endowed with all the modern facilities for handling cargo, and has sent out to Europe and the United States a full report with all necessary data submitting the project to capitalists and contractors, with the request for propositions to build and operate the port. It is estimated to cost about $13,000,000 gold.

La Plata port and city were built by the provincial government when in about 1880 the national government occupied Buenos Aires as the capital of the nation. La Plata is an excellent port built on the shore of the Rio de la Plata. It is about 35 miles from Buenos Aires, and the port opened in 1900 cost about $14,000,000 gold. The opening of the national port at Buenos Aires has drawn most of the commerce from La Plata but it is capable of being made, with a comparatively small sum of money, deep enough in its entrance channel, five miles long, and its port areas, to accommodate vessels of 26 feet draft. The ports of Buenos

Aires and La Plata are both approached from the sea over very troublesome shoals that extend entirely across the River Plata between here and Motevideo. The Government is turning its attention to these obstructions and possibly will buoy the whole course of vessels the entire distance from Buenos Aires to the ocean, practically the whole length of the River Plata over 120 miles long.

The remaining port of importance, and rapidly growing, is Bahia Blanca, outside of the River Plate in the South. It is the principal shipping port of agricultural products by the Great Southern Railway which has the largest system in the Republic. This port is in an estuary of the ocean and is a protected harbor; in fact the terminal of the railway is about 35 miles from the open ocean. The railway is building a steel pier and there will be, when all the works are completed, over half a mile of wharf frontage supplied with electric cranes. The national government is building in this estuary at Puerto Militar, a system of dry docks and basins on a large scale. The first dry dock, one of the best in the world, will soon be ready to admit vessels.

Like most South American countries, Argentina has had a checkered experience since its discovery in the year 1515 by Don Diego de Solis, the Spanish navigator, who gave to a noted island at the head of the River Plate the name of his second officer, Martin Garcia. The city of Buenos Aires was founded by another Spaniard, Don Pedro de Mendoza, in 1535, nearly a hundred years before the pilgrims landed on Plymouth Rock. This country, like our own, was occupied by Indians, who though possibly not as wild and savage as some of ours, were sufficiently troublesome to make the life of the early settlers anything but pleasant.

The intervening years to 1810 were full of revolutions, fighting, bad government, and so full of political changes that it is hard to follow them. But on the day that is celebrated here, as we celebrate in the United States the Fourth of July—May 25th, 1810—the committee of the people practically declared the intention of being free from the dominion of Spain, although it required a dozen years to rid the country of its military power, for after Argentina, Paraguay and Uruguay, neighboring countries, were free, Argentina had a difficult task of driving the Spaniards from Chili and Peru.

One of the most illustrious presidents and benefactors of the Republic was Sarimento; who after some years residence in the United States and witnessing there the great development in education, conceived the idea of bringing here quite a number of young lady teachers from the United States who have done much in all these years since 1868 to spread education, and sound methods of teaching. Several of them are still here and still teaching as directors of normal schools and other important educational institutions.

After the civil war of 1880, Gen. Julio H. Roca became President, and his administration was noted for driving back the Indians to south of the Rio Negro,—one of the southern rivers, and for developing the railroad system of the country. Railways have had quite an extensive development within the last twenty years. In 1867 there were 355 miles, in 1880, 1,563 miles, in 1890, 5,862 miles, and in 1901, 10,291 miles of which 1,243 miles belong to the Government and 9,048 to foreign companies. As compared with the United States the mileage is about six per cent. There are three gauges, 5½ feet which is really the standard; 4 feet 8½ inches; and a narrow gauge, usually about 3 feet 3 inches, or 1 metre. The total length of telegraph lines is 27,602 miles, while in the United States the Western Union alone has 192,705 miles of poles and cable.

Statue of Gen. Don Martin, Buenos Aires, S. A.

President Roca is now serving his second term, and through his wise administration and his persistence, the great waterway systems of the republic are being improved, harbors built, commerce encouraged, and the means of transportation generally enlarged and economized. Nor should the name of Dr. Emilio Civit, the Minister of Public Works, be omitted in this connection, for it is one of his principal purposes and most earnest desire to remove the obstacles to commerce that lie in these great rivers, and to carry the ocean navigation to the highest points possible, and then the river navigation, through existing shoals and rapids, to the far Bolivian and Brazilian interior thousands of miles away.

The wheat area of the Republic sown in 1901 was about 8,400,000 acres, mostly in four provinces—Buenos Aires, Santa Fe, Cordoba and Entre Rios. The wheat export to foreign countries in 1900 was over 80,000,000 bushels. Iron and steel industries are important, although there is practically no ore and coal in the country. In 1895 there were 154 iron foundries and 66 repair shops with a capital of $15,000,000. Every class of machinery is now manufactured, even to small engines and boilers. There are some valuable copper mines containing gold and silver, also rich veins of gold and silver with recent discoveries of iron ore, but these various products have not been developed to any great extent. The total value of minerals exported in 1900 was but little more than $262,000 including gold, borax, copper, marble, silver ore and lead ore.

The Transandean Railway.

Argentina is a protectionist country and its resources for conducting the Government are largely raised from the custom dues. In 1899 the imports free of duty amounted to nearly $15,000,000 (gold) and those subject to duty $102,000,000 (gold). The money of the country is on a paper basis and the minimum value of a dollar was fixed in 1899 at 44 cents gold or 127 per cent premium. The market value of a gold dollar expressed in paper money varies now between $2.30 and $2.34, and the gold dollar is at a slight discount over that of the United States.

Spanish is the universal language, but as might be expected in the cities, which are mostly cosmopolitan, French, Italian, English and German are spoken almost everywhere. As English money and Englishmen have done more to develop the country, have built and operated nearly all the railways, many of the great estancias, and do the commercial business, the English language is very generally used in railroad and navigation circles.

The province or State of Buenos Aires, is in many respects the most important state in the Republic. It is almost entirely within the limits of the pampean plains and is remarkable for its stock. It covers about 125,000 square miles or larger than Illinois, Indiana and Massachusetts combined. It has 1,200,000 inhabitants who own 10,000,000 head of cattle, 62,000,000 sheep and 2,200,000 horses. The value of its agricultural and pastoral products, not counting wool, is estimated at $740,000,000.

The early history of the city of Buenos Aires, like that of Argentina, is full of trouble. Destroyed, rebuilt, and then from 1650, when there were four hundred houses, it grew slowly under the old Spanish regime, and later under dictators and bad rulers, it slowly advanced in spite of an unstable government. In 1852 when the noted Rosas was turned out it had 76,000 inhabitants. Chicago was then passing through the hard trials of a little western town and had not more than 20,000 people. In 1864 Buenos Aires had 140,000 inhabitants and Chicago about the same; in 1869,

Avenue Alvear, Buenos Aires, S. A.

178,000, but Chicago had already started on its phenomenal growth and reached over 300,000. In 1887 Buenos Aires had 409,000 and Chicago 1,000,000 and still growing at a rate of 5 per cent per annum. At present Buenos Aires has 810,000 people and is growing at the rate of about 4 per cent per annum. It is now the largest city south of Philadelphia, if we except the Chinese cities. The city is on the right bank of the River Plate, a sloping bank 50 or 60 feet above the level of water rising up to considerably greater elevations in the center of the city. It is about 120 miles from the sea at Montevideo. Its area is 44,830 acres, while that of Paris is only 19,280 and Berlin only 15,625. As far as natural conditions permit, the streets are laid out in the form of a chess board, the streets being about 360 feet apart from center to center. In the central part of the city the streets are narrow. It is difficult for three carriages to pass, there are, however, a few streets 33 feet wide and one or two avenues about one hundred feet wide. There are 72 parks and small areas outside the main streets with a combined area of about 1,400 acres. These parks are more tastefully laid out and more neatly kept than can be found in any other country, Paris excepted. In fact in many respects the city in its streets, lights, parks and structures resembles Paris, except there are more one story residences than in Paris. The prevailing style of residence is Spanish with a patio—an open area—and the rooms all facing it, and in this patio is a garden and fountain when the proprietor is able to have it, if not there are pots of flowers very much like the ordinary city house in Mexico. The streets are nearly all paved with wood, hard suitable wood of the country, also asphalt, granite blocks, macadam and rubble. No city has better pavements in the central parts but in the outskirts much of the pavement is very bad and uneven, merely rubble. There is no city anywhere with more lines of street cars, in fact with the exception of two streets, there is a line in every one of the principal thoroughfares, and leading out to the pleasant suburban towns Belgrano, Palmero and Flores there are electric lines similar to those in Chicago and other American cities using the overhead trolley. All the equipment from rails to trolley comes from the United States. There are now 275 miles of street car lines in the city which carried in 1900, 116,447,982 passengers. The history of lighting the streets in the city is quite interesting and shows that the city keeps pace with others in this respect. The first record of public lighting was in 1778 when the city had lamps in the shape of a tin of horse oil with a wick, then came tallow dips, then oil lamps, then came gas in 1885, and in 1888 electricity began to replace it in part, and on December 31st, 1900, the city was lighted with 889 arc lamps, 318 incandescent lamps of 16 candle power, 14,084 gas lamps, and 8,590 coal oil lamps. And there were 36 electric light stations with a capital of $9,000,000 gold, and with a capacity of 23,300 electric horse power.

In 1868 there was a terrible epidemic of yellow fever due in large part to unsanitary conditions, but immediately the city began a very extensive system of water and drainage works costing $33,000,000 gold, discharging the sewerage 15 miles distant, and the storm waters by great intercepting sewers, just now being completed, into the river in front of the city. The water of the River Plate is healthy but muddy, and it is settled in settling reservoirs before being delivered to the distributing reservoir on one of the highest points of the city. These works altogether have made Buenos Aires one of the healthiest cities in the world as the death rate proves.

Distributing Reservoir, Buenos Aires Water Works.

The climate, taking the whole year around, is very equable and very agreeable. The parks are always green, pines, palms, and a species of banana plants are seen everywhere, and there are flowers all the year in the open. The general style of the city is cosmopolitan in buildings, stores, residences. and in the dress, habits and customs of the people. Among the foreign population are Spanish, French, Italian, English, German, Swiss, and North Americans as we are called,—we number only about 1,400.

As might be expected of such a progressive country, adopting promptly new inventions, the telephone and telegraph have come, though there are many improvements in the telephones which have not been introduced here yet. There are four cable companies keeping up a close connection with all parts of the world, though the cost of cabling is quite heavy, one dollar gold per word. The service is very good and prompt, the time of transmission between Buenos Aires and London via Galveston and Western Union lines and cables is 60 minutes and with New York 30 minutes. When we consider the distance and route, we are astonished at the working of this line which crosses over the Andes, 10,000 feet above sea level, tunnels under the snow and avalanches and reaches the Pacific Ocean only to take successive leaps by loops along the coast to Tehuantepec in Mexico over the Isthmus, across and under the waters of the Gulf of Mexico to Galveston, speeding then its swift flight over the poles of the Western Union to New York City and then without stopping to rest plunges into the depths of the Atlantic Ocean and talks to the receiver in London 60 minutes after it left the operator's fingers in Buenos Aires.

At Buenos Aires there is a large business with New York by means of five steamship lines and through New York with Chicago and vicinity from which are shipped a large amount of agricultural machinery of all classes from cultivators and plows to great steam threshing machines of the J. I. Case Co., of Racine, Wis. Not only from Chicago, but from all manufacturing districts of the country, the trade with this country is rapidly increasing. One sees our machinery everywhere and everywhere it is considered the best; for instance, "Baldwin" locomotives, "Jackson & Sharp" cars, and the "Harlan & Hollingsworth" machinery.

The American freight cars of 25 and 30 tons are replacing the old Belgian, French and English 6, 7 and 10 ton cars. If the American freight cars are not all made in the United States, they are copied exactly from ours. The most approved bridges are from the United States. I have recently been over several and examined one on the Transandine Railway built by the Phœnix Bridge Co., of Philadelphia, all excellent bridges and giving entire satisfaction. The Boston Bridge Company is also sending out some very good bridges. The horse cars by John Stephenson of New York, electric cars by the J. G. Brill Co., and the Westinghouse Co. are doing well here. I might enumerate many other United States products. I can truly say that the prospects of American trade with this country are exceedingly good.

A word about my own work. I am the only American civil engineer in this country in the employ of the Government. My position as Consulting Engineer of the Ministry of Public Works, particularly in its river and harbor improvements, places me in intimate relation with many officials of the Government, and after over a year's experience I am glad to say that they are all not only professional but personal friends. I have had in the past a very large and varied association with the leading railroad, bridge and harbor engineers and officials in the United States, including government officials at Washington, and though all these relations have been most cordial, I have never passed a pleasanter nor more satisfactory year professionally, than the last has been.

# CLV.

## SCOPE, EXTENT AND CONSTRUCTION OF THE UNDERGROUND CONDUITS OF THE ILLINOIS TELEPHONE AND TELEGRAPH CO. IN CHICAGO.

By Mr. George W. Jackson.

*Presented Sept. 17, 1902.*

As the first part of the subject is the scope of the company's intention, I will say that Mr. Wheeler and the board of directors of the company have directed me to build a telephone system composed of conduits and cables which would accommodate 100,000 subscribers, and that it is with the intention of building an exchange of this size that we have proceeded with the work. The first thing that becomes necessary in building a telephone exchange is the foundation and what would be classed as the foundation by us, the conduit system. Experience has taught me in the past that up to the present time telephone companies in different cities have made a serious mistake by not building their conduit system large enough to accommodate their increased business from year to year in its reasonable expansion. Fortunately I have acquired a vast experience in the building of conduit systems for telephone companies, and have seen the mistakes that they have made by not building their conduit systems on more extensive plans. With this knowledge, and also with the knowledge that I have obtained as to the conditions of the streets of Chicago, where it would become necessary to build a conduit system, or, in other words, in the streets of the down town district, some place had to be found where a conduit system could be built of the size required by the company. After thoroughly canvassing the situation it was found there was no available space left where a system could be built which would accommodate an exchange of 100,000 subscribers. An illustration of a cross section of our 6x7½ feet lateral tunnel is shown in Fig. 1. This size conduit would only allow us to place enough cable for 25,000 telephones, coming in from one direction to a central exchange. After thoroughly canvassing the requirements of an exchange for 100,000 telephones, and figuring on the space required, we found that the space was not to be obtained immediately below the surface, on account of the present congested condition below the streets. This is shown by Fig. 2,—the conditions as they now exist at the intersection of LaSalle and Washington streets. The space below the paving is almost completely taken up by water and gas pipes, sewers and conduits for other companies. Mr. Wheeler and myself then made further investigations relative to finding some available space where a conduit system could be built, and, finally, after getting what knowledge could be obtained, we found, from the conditions of the soil underlying Chicago, that a deep tunnel conduit system could be built without any danger to adjoining property, or without interfering with other corporation rights. After finding out the practical situation relative to building

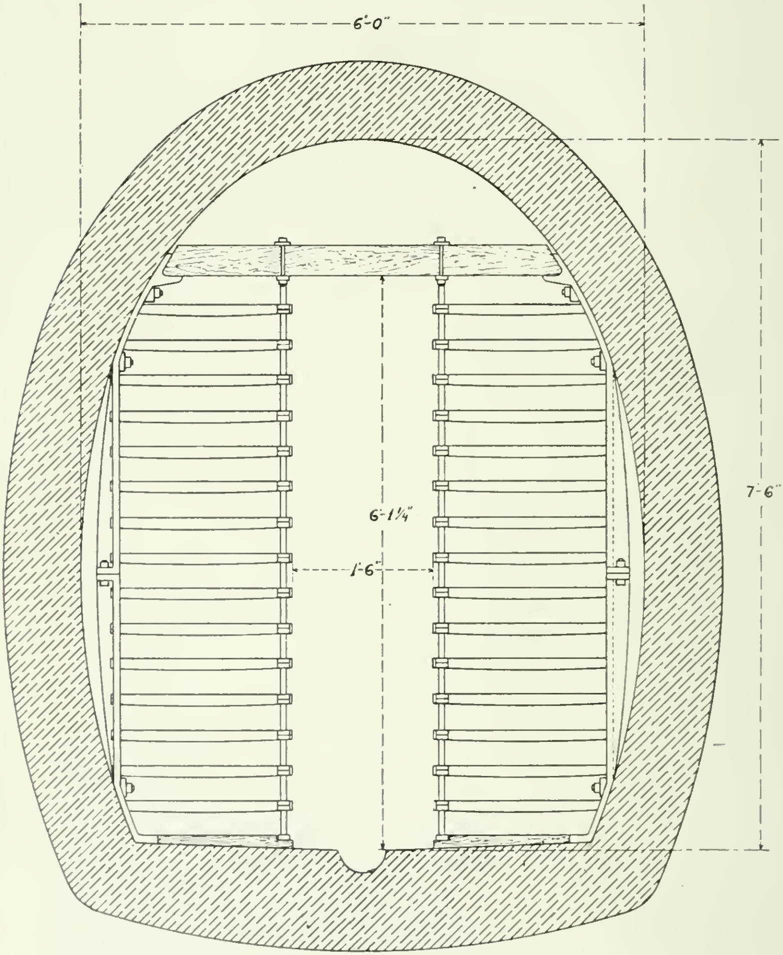


Fig. 1. Cross Section of Lateral Conduits, Showing Racks for the Cables.

conduits by the tunnel method, and after thoroughly satisfying ourselves that we were right, Mr. Wheeler then asked the city authorities to grant him a permit under the plans as submitted in accordance with the ordinance which allows him to construct his conduit system. After obtaining the permit, work was started at the first shaft, or what is known as shaft No. 1. This is on the alley between Madison and Monroe streets, west of LaSalle street, and Fig. 3 shows the location of the shaft, the air compressor, belt conveyor, concrete mixer, the elevator, elevator machinery and shaft. The reason that I had this particular shaft illustrated was for the purpose of showing the method we had adopted in the execution of our work. It required considerable time and thought in locating our shafts, as we had to show property owners that by the location of them we would in no way inconvenience their tenants. After locating shaft No. 1, we leased other basements for other shafts, which are located as follows:

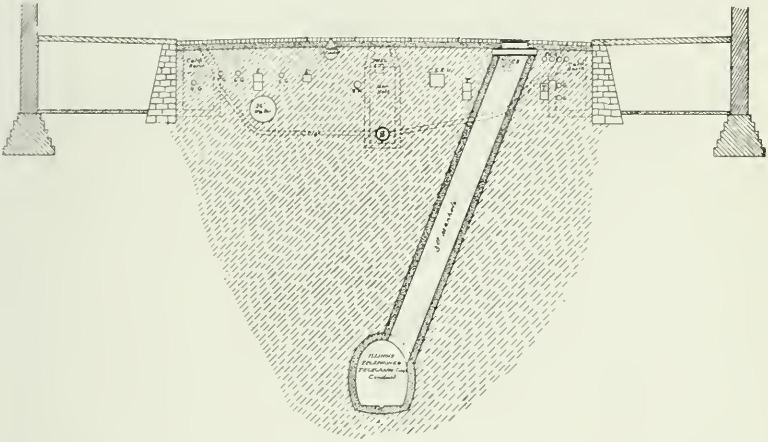


Fig. 2. Cross Section of Street showing the space below the pavement—occupied by Sewers, Water and Gas Pipes and Conduits — also showing the Lateral Conduit and Manhole Connection.

Shaft No. 2, on Dearborn street, just north of the Fisher Building.
Shaft No. 3, at 113 and 115 Franklin streets.
Shaft No. 4, at State and Lake streets.
Shaft No. 5, at Randolph and Clark streets.
Shaft No. 6, at Harrison and Clark streets.
Shaft No. 7, at State street and Eldridge court.
Shaft No. 8, at Congress and Market streets.

The location of these shafts, also shown on the plan of work as projected, was such as to allow us to proceed with the building of the conduits covering the down town district. The ultimate scope of our work is intended to extend on the South Side to 71st street, on the West Side to Kedzie avenue, and on the North Side to Fullerton avenue, it having been decided that the building of the conduits by tunnel methods would be the speediest and most economical. Extending from the tunnel system on the South, West and North, it is the intention to build side branches covering the entire city. These side branches will largely be constructed by the method of tunnelling, as far as it is economical. From this system it is our purpose to construct a sufficient number of miles of tile conduit system in outlying districts, it being the intention to reach all of the available territory, in order to accommodate all classes of subscribers. The purpose of Mr. Wheeler and the board of directors is to install a telephone in every residence, as well as in every business office and manufactory in Chicago.

After having our plans approved by the proper city authorities, and shortly after starting with the building of the conduits, we found there was not in existence an accurate map of the streets. We decided that no further work could be done until such time as a new survey was made, and I had our engineering department make a new topograpical survey. To make this survey required considerable time, it being impossible for our engineers to run lines until after the congestion of traffic was off the streets at night, thus compelling us to run our lines after ten o'clock at night and before five o'clock in the morning. As can be appreciated by engineers, doing work under these conditions, was very slow and tedious, but, while it was slow and expensive, the results of this survey has amply repaid the company, as can be appreciated by engineers when I say that some thirty-eight different tunnel connections were to be made. This part of the engineering work was under the management and direction of Mr. Alfred Slade, an engineer who has been connected with me for several years.

After this new survey had been made, and the work had been checked and approved by the engineer appointed by the Department of Public Works, we were then ready to proceed with the work in the down town district. Upon notifying Mr. Ericson, the City Engineer, of our intention to proceed with the work, we were informed that he would not allow us to proceed in the way provided for by the first permits that were granted; this was on account of the number of manholes that would be required by us on the streets, he taking the position that the building of manholes such as we would need, would be obstructions to a subway, which in his judgment the city would some day build. Permits, as originally granted, the company allowed us to build manholes, as shown in Fig. 2. His position was that he could not allow us to construct such manholes, and also that he believed we were too near the surface. This compelled us to adopt a method whereby the building of manholes would be obviated. After designing numerous cross-sections, and carefully figur-

# GENERAL PLAN OF SHAFT NO. 1.

ILL. TEL. CON. CO — A. G. Slade Asst. Engr.

Approved George W. Jackson
Gen. Mgr. & Engineer

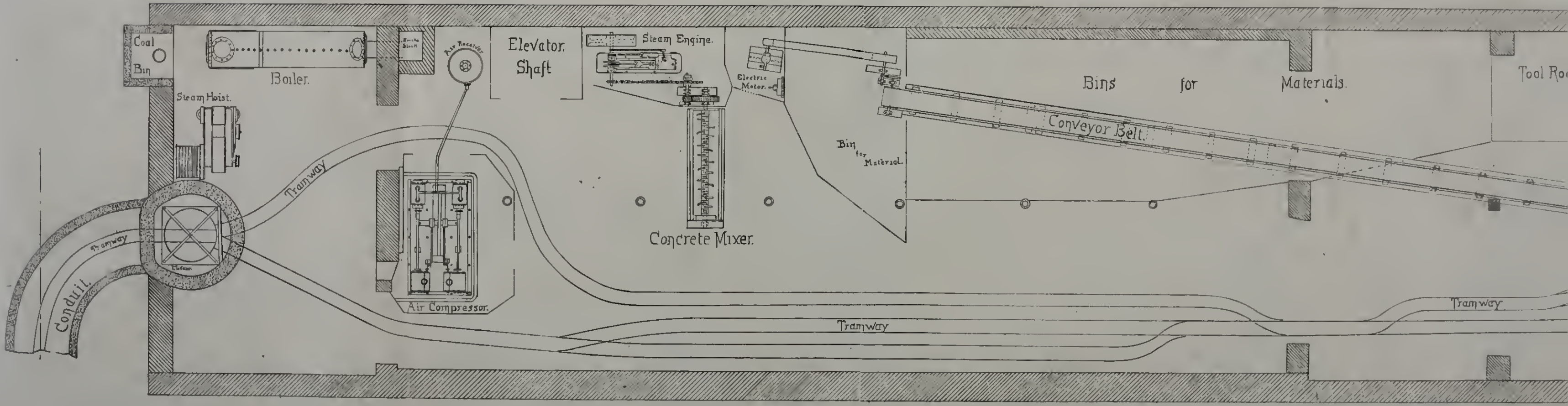


Fig. 3.

ERAL PLAN OF SHAFT NO. 1.

ILL. TEL. CON. CO. Alf Slady Asst Engr.

Approved George W. Jackson
Gen. Mgr. & Engineer

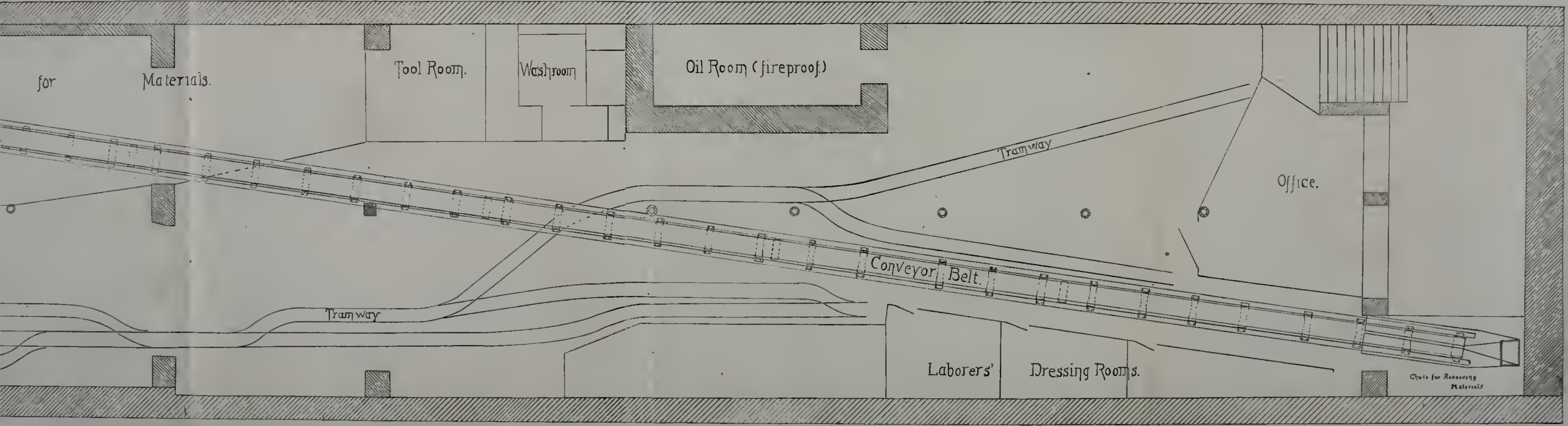


Fig 3.

ing out what space would be required to accomodate our business, the size 12 feet 9 inches by 14 feet for the trunk lines was submitted for approval.

In going over the situation with Mr. Ericson, City Engineer, he finally decided that a 12 foot 9 inch by 14 foot size could be permitted, and this would enable us to lower the reels and cables from our warehouse down a shaft to the level of our conduit system, and transporting the car, reel and cable as shown in Fig. 4 through these trunk conduits around to the different lateral systems. By this method of lowering the reel and cable and transporting it around through the trunk system, we avoided the building of manholes. This method being finally approved by Mr. Ericson, he decided that as we already had the right to use the space at the level we intended to build, there seemed to be nothing in the way of allowing us to build a tunnel the size of 12 feet 9 inches by 14 feet, and he finally granted us a permit to do this, with the understanding that we would drop the roof of our 12 foot 9 inch by 14 foot tunnel so that it would not come any closer than 24 feet 6 inches to the surface. In our original permits, as granted, we had the right to construct our conduit as close as 22 feet 6 inches from the grade. After obtaining the permits we proceeded with the construction of our lateral conduits, and at the present time we have constructed about twelve miles. The table here, shows the number of yards of stone, gravel, barrels of cement, and number of yards of excavation in this twelve miles of completed lateral conduits.

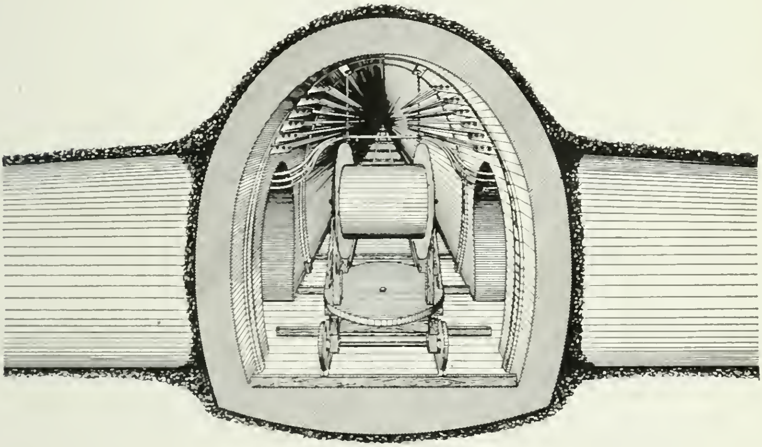


Fig. 4. Intersection of Trunk and Lateral Conduits, and showing a Car and Reel of Telephone Cables.

WORK DONE AND RATE OF PROGRESS. SEPTEMBER 1, 1902.

Total No. of feet constructed........................61,726

WORK PER SHAFT.

| SHAFT | No. Feet | Working Days | Average Feet per Working Day |
|---|---|---|---|
| No. 1 | 18,730 | 294 | 63.1 |
| No. 2 | 14,595 | 247 | 59.2 |
| No. 3 | 2,464 | 118 | 20.5 |
| No. 4 | 17,510 | 229 | 76.1 |
| No. 7 | 1,244 | 63 | 19.4 |
| No 8 | 7,183 | 176 | 40.1 |

Average working days from all shafts........................188

Average feet per day from all shafts........................328

Total excavation from all shafts........................175,000 cubic yards

MATERIAL USED.

| | |
|---|---|
| Cement | 90,000 barrels |
| Stone | 30,000 cubic yards |
| Gravel | 60,000 cubic yards |

After satisfying ourselves as to the nature of the sub-soil, we settled upon the method for carrying out the work. Experience having taught me that the pneumatic system would be the most economical and safest, we adopted it. While it was not altogether necessary for us to use this system, as the nature of the soil we would have to go through is such, that it would stand without caving or swelling, we put in the pneumatic system more for the purpose of being protected from labor troubles, than anything else. With that system, if the men should go on a strike, we would have no anxiety, as there would be no danger, if the work was left for a time in an uncompleted state.

In installing our pneumatic system, airlocks were placed just outside the several shafts. These airlocks have iron doors with frames imbedded in the concrete, the locks being long enough to accommodate the work, in some cases as many as ten cars. I do not know that it is necessary to describe the operation of the airlocks in detail. However two airtight doors are used, one at each end of the lock. The locking-in process is effected by allowing the cars to enter through the outer door, and then the door is closed. The air under pressure is then admitted from the uncompleted tunnel, allowing it to flow into the lock, thus equalizing the pressure in the lock with that in the tunnel; the inner door is then opened and the cars are run on to the headings. In locking-out again, the inner door is closed after the cars have entered the airlock, the valves opened at the outer door allowing the air to escape and thus equalizing the pressure with the completed part of the tunnel (which is open to atmospheric pressure) after which the outer door is opened and the cars go on to the shaft.

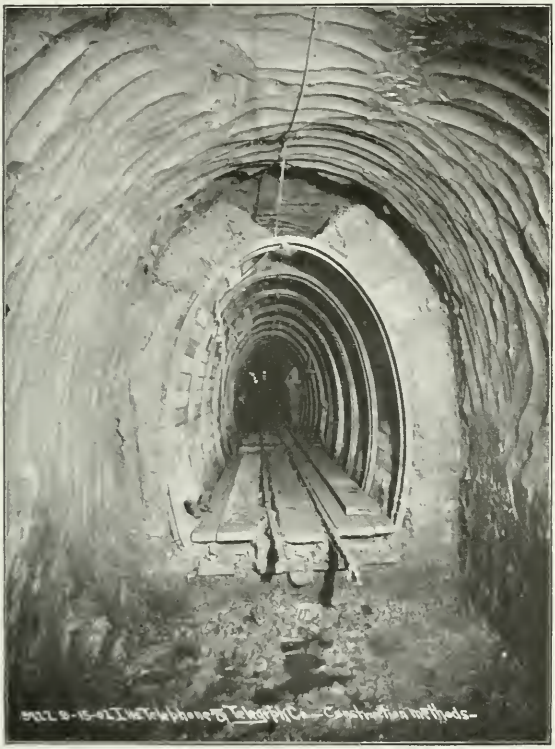


Fig. 5. Lateral Conduit Under Construction

Fig. 5 shows the ground as excavated ahead of the completed conduit, after the mining has been done. The concrete is then placed in the bottom and thoroughly tamped, the lagging placed on top of the concrete, iron ribs made of channel bars being placed on the bottom, and lagging laid at the sides against these. Fig. 6 shows these frames or ribs made of 3 inch channel bars, and which are placed three feet apart, After the ribs have been placed the lagging of 2-inch plank is then placed behind the ribs and the concrete thrown in behind the lagging in layers of six inches. As can be seen by illustration (Fig. 5), the use of concrete absolutely avoids any chance of settlement of the earth as the concrete is tamped into the entire space between the lagging and excavation. It makes no difference how irregular the digging or mining has been done, as every void is filled. This method of placing concrete is carried up until it reaches what is known as the key, as shown in Fig. 5.

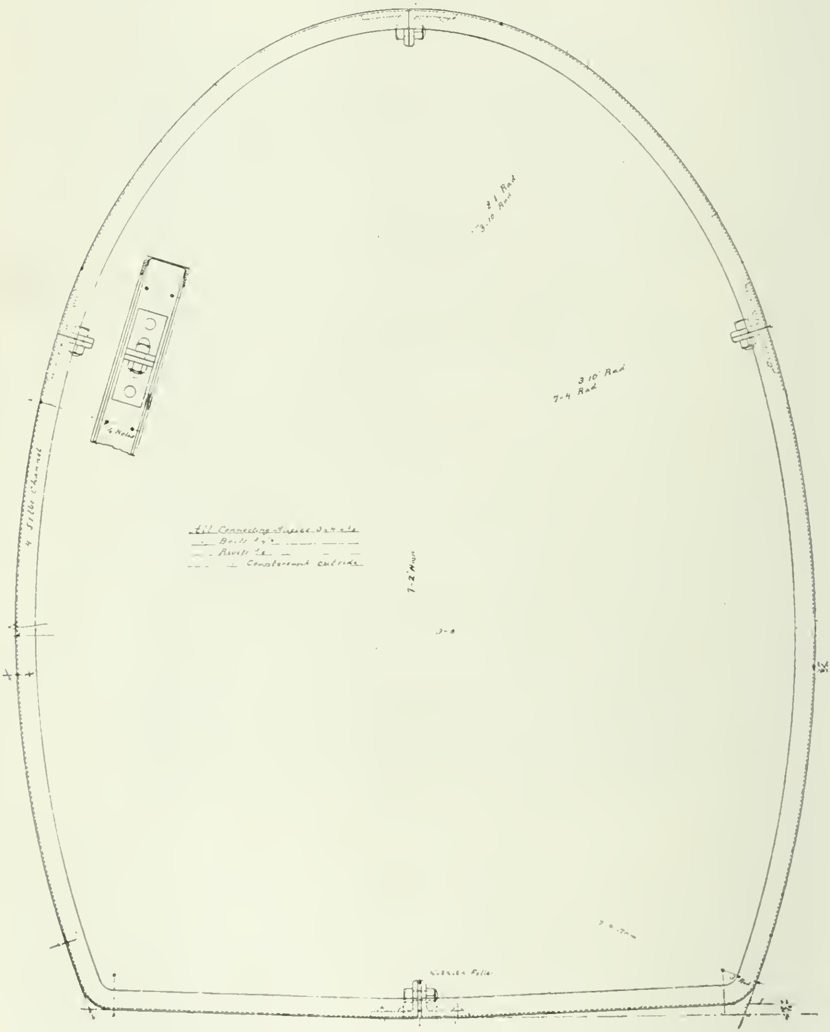


Fig. 6. Frame and Form for Lagging of Lateral Conduits, made of 4 pieces of 3-inch Channel Bars.

As it is most important to have the key properly placed, it is built in sections of three feet, or, in other words, the key boards are only three feet long. These are also placed on the ribs, which are three feet apart. The concrete is then thrown in, and after three or four shovelfuls are thrown in, the concrete is rammed, care being taken that the concrete is rammed so that every void is filled. By this manner of working any possible chance of the ground settling is avoided. In proceeding with the concrete work the face of the preceding day's work is cleaned, and a plaster coating of cement, made in proportions of one to one, of sand and cement, is plastered on the old work. This forms a seal, allowing the old work to have a bond with the new work, making it almost an entirely homogeneous structure.

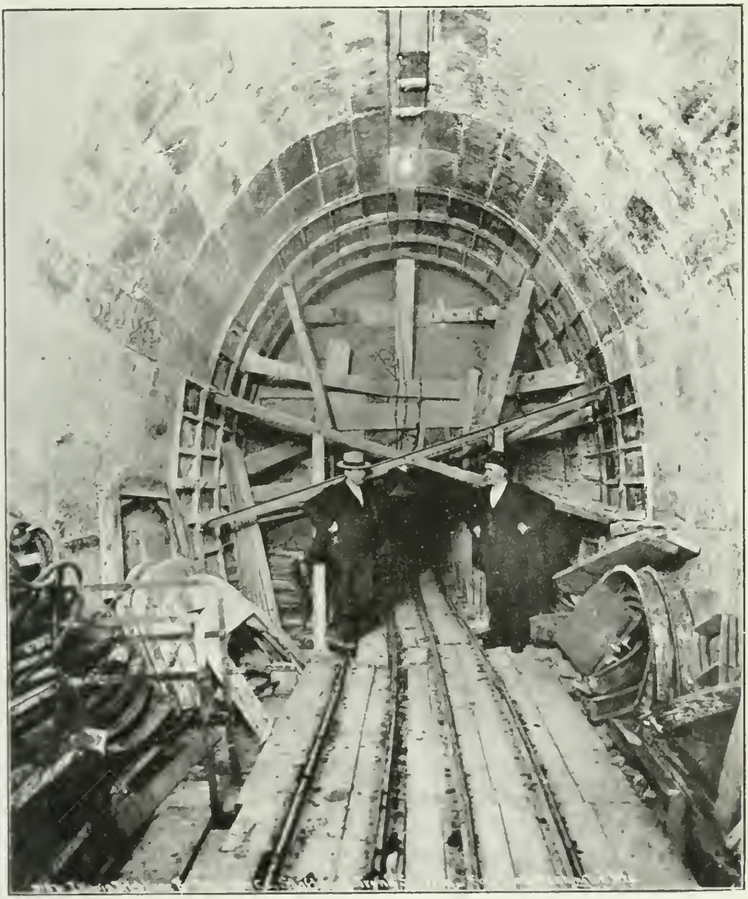


Fig. 8. View of Trunk Conduit Under Construction

In Figures 7, 8 and 9, is shown another system of ribs and lagging which was used in the trunk system. Here the ribs are made of five inch channel irons, and the lagging plates are made of No. 12 steel. These steel ribs and lagging were used as an extra precaution on account of the extra weight of the concrete, as well as to allow the men to thoroughly tamp the concrete without having the work left in irregular shape.

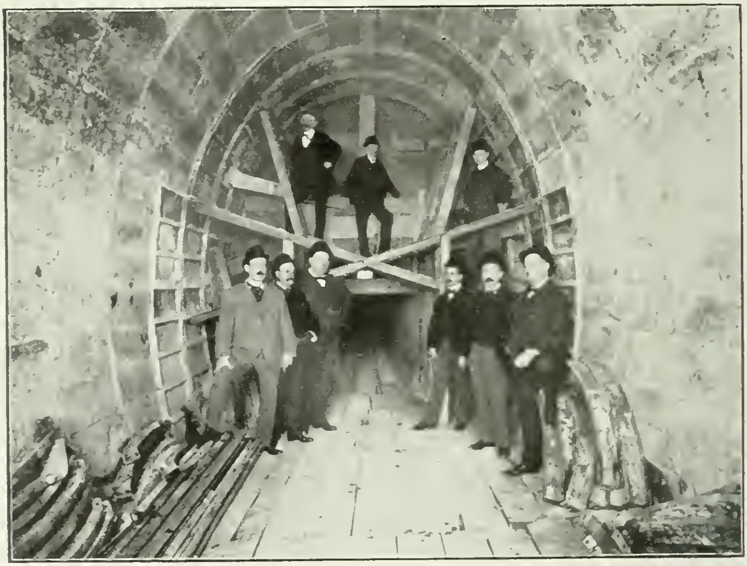


Fig. 9. View of Trunk Conduit Under Construction.

Figures 8 and 9 show the trunk system with steel ribs and lagging in place. I would like to mention that the walls of the 6 feet by 7 feet 6 inch lateral conduits are constructed with 13-inch bottoms and 10-inch walls of concrete. The trunk system conduits are constructed with 21-inch bottoms and 18-inch walls of concrete.

The work was carried on by three shifts of men working eight hours each. The first shift of miners went on at four o'clock in the afternoon and worked until midnight; the second shift went on at midnight and worked until eight o'clock in the morning; the third shift, which was known as the concreting shift, went on at eight o'clock in the morning and worked until such time as they were through. The work of the third shift was arranged in such a way that they would get through their work so that the miners could go to work at the regular time, at 4 p. m.

The distance excavated by the two shifts of miners averaged about 21 feet at each heading. The number of working headings averaged, taking in all the different shafts, about fourteen. It required about twenty men to operate each heading or a total of about 850 men were engaged on the tunnel construction. About 600 other men were employed in the office forces, the hauling of gravel, stone, cement, and the teamsters that were employed in hauling away the excavated material.

The cement used for the making of the concrete was American Portland (Atlas and Chicago AA). All tests of cement were made by the company, and each and every barrel was tested and subjected to a 14-day test before being accepted and under very rigid specifications. Most of the concrete was made with the mixture of five parts of broken stone and screenings to one part of cement; but a large part of the concrete was composed of mixed gravel and sand which was used in the same proportions as broken stone, five parts of gravel to one of cement. This mixture of concrete was used on the straight work of the conduit. At the intersections, a mixture of four parts stone or gravel to one of cement was adopted.

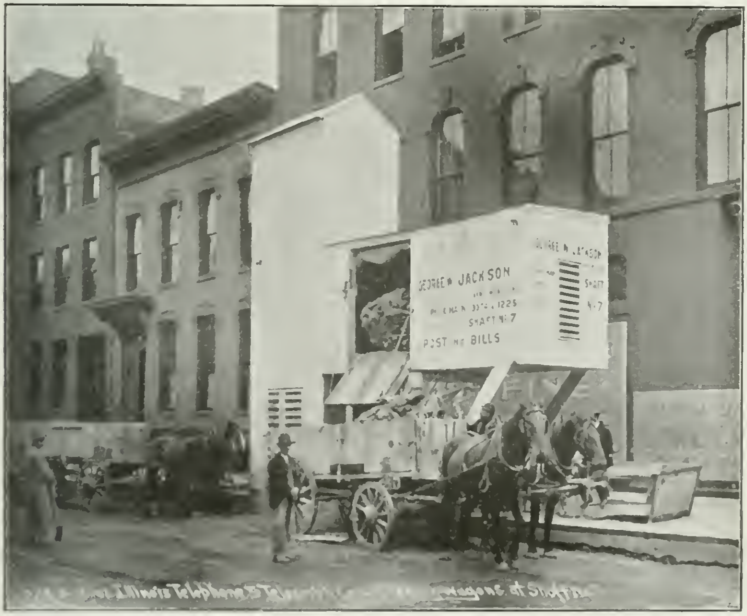


Fig 10 Elevator House, to lift the excavated clay that it may be dumped into wagons to be hauled away to the Lake Front.

In managing the work, in order to have everything run smoothly, considerable care had to be exercised to see that the excavated material was promptly disposed of, as any delay in disposing of the excavated miateral would cause delay. A large equipment of tram

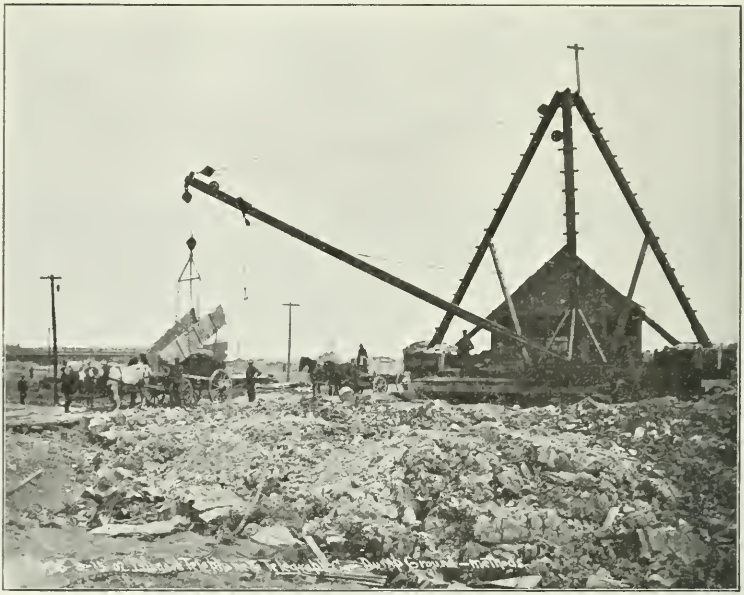


Fig. 11. Unloading the excavated clay at the lake front. Lifting away the sideboards of the wagon bed.

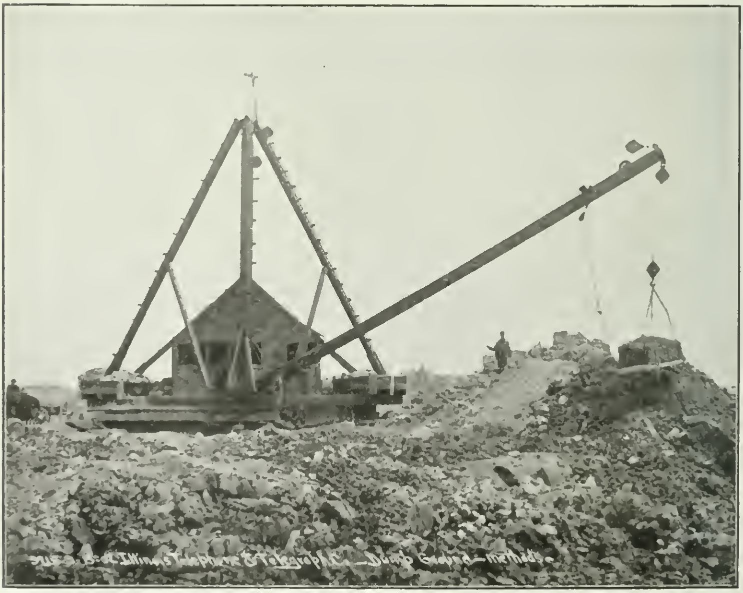


Fig. 12. Wagon Bed Bottom swung round to dumping place ready to spill.

cars were built, some 900 in number. The tram cars were built to run on a gauge 14 inches wide, a double track system being laid through the entire tunnel system. Experience has taught me that the most economical way of handling large quantities of material was in small portions, and especially in the construction of a tunnel, so that for handling concrete and excavated material small cars were used, 20 inches wide inside and 48 inches long. From the knowledge I have obtained in the management of this work I believe the smallness of the cars was largely instrumental in successfully carrying out the building of the twelve miles of tunnel in the short space of time it has taken to construct the system. One reason for this is, that if a car jumped the track, an ordinary man could set it back on the track. This kept the moving of excavated material going on continuously without any interruption. Also in the transportation of concrete, the smallness of the cars made it possible for the men to more readily and speedily handle the concrete, thus obviating any chance of its becoming set. This was an important factor, as it has done away with any concrete being used which had received any initial set.

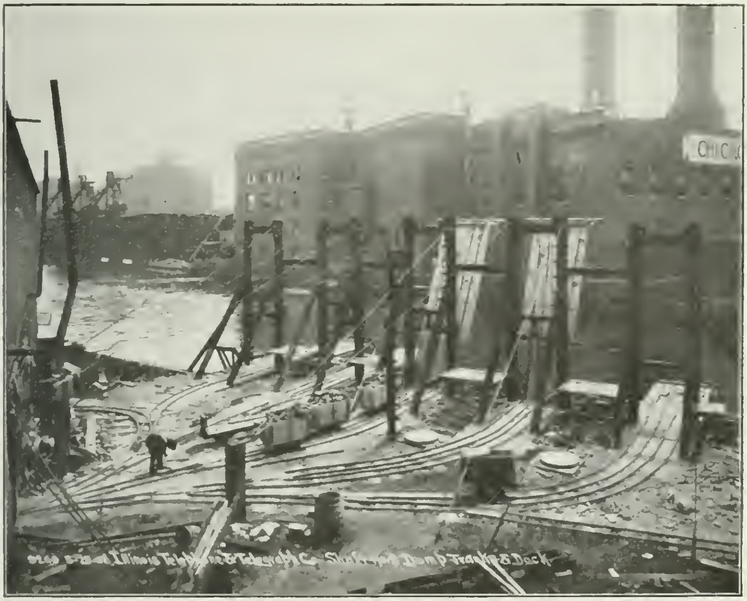


Fig. 13. Tracks and Movable Platforms for dumping the excavated clay into scows in the river.

The cars were hoisted by a power driven elevator up the shafts to the second floor of the building, or to a head-house built on the curb line, and the material dumped into wagons standing on the street or alley. The dumping of excavated clay into a wagon is shown in Fig. 10. Much of the material was deposited at the Lake Front, and for unloading the wagons a 10-ton stiff-leg derrick was installed. This first hoisted away the sides of the wagon boxes (Fig. 11), and then hoisted the entire bottom of the wagon with its load. When this was swung round ready to dump, the chains on one side were unhitched and the clay dumped, as shown in Fig. 12.

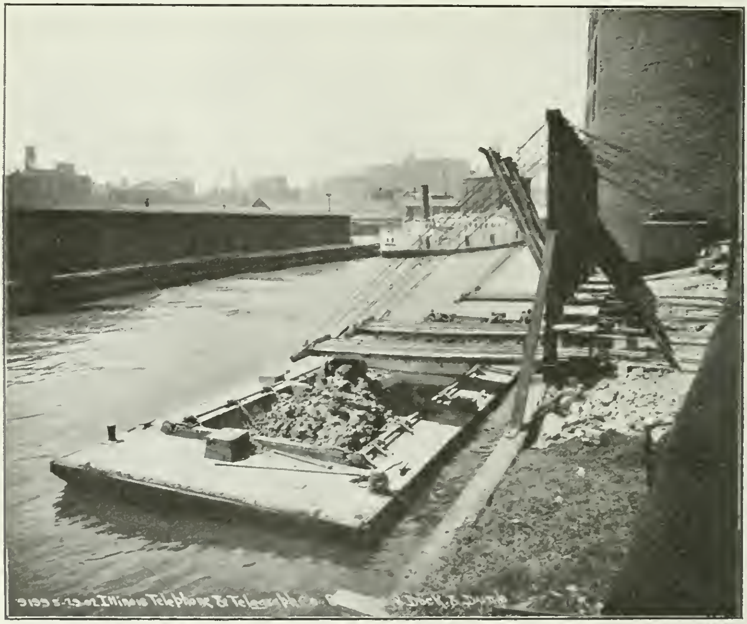


Fig. 14. Loading scows in the river with excavated material from Shaft 8.

The reason I have touched upon this part of the construction is from the fact that it was imperative that this branch of the service should be kept in continuous operation while the miners were at work, as any delay would have been expensive, delaying the operation of the miners. The hauling away of the excavated material was done mostly at night, between 5 p. m. and 7 a. m., to avoid interference with the usual street traffic. I would like to mention that great credit is due Mr. William Newman, who had charge of this branch of the work. His management was such that there was no delay whatsoever, regardless of the conditions of the

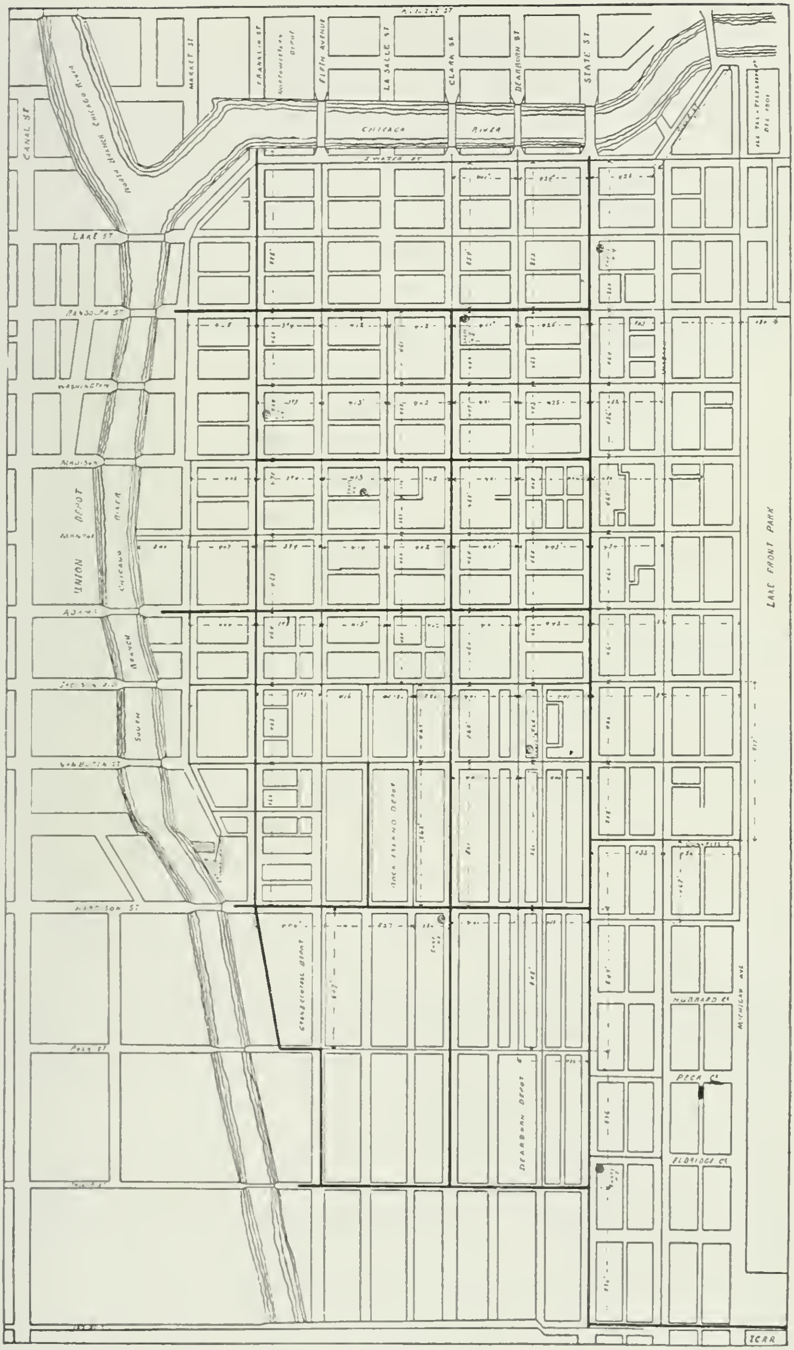


Fig. 15. Plan of streets in the down-town district showing the Conduit System as planned. Heavy lines indicate the Trunk System of Conduits, and the light lines indicate the Lateral Conduits.

weather, and as is well known we have had some very severe and stormy weather, during the past year. Another method that we adopted for handling the excavated material was, at what is known as Shaft No. 8, which is located on the river at the foot of Market Street. At this shaft we constructed an incline from the conduit, and used an endless conveying chain with dogs, constructed in such a manner that they took hold of the axles of the cars and conveyed the cars up the incline to the surface of the ground. They were then run on the tracks to the edge of the river, and out on platforms extending over dump scows moored to the dock below.

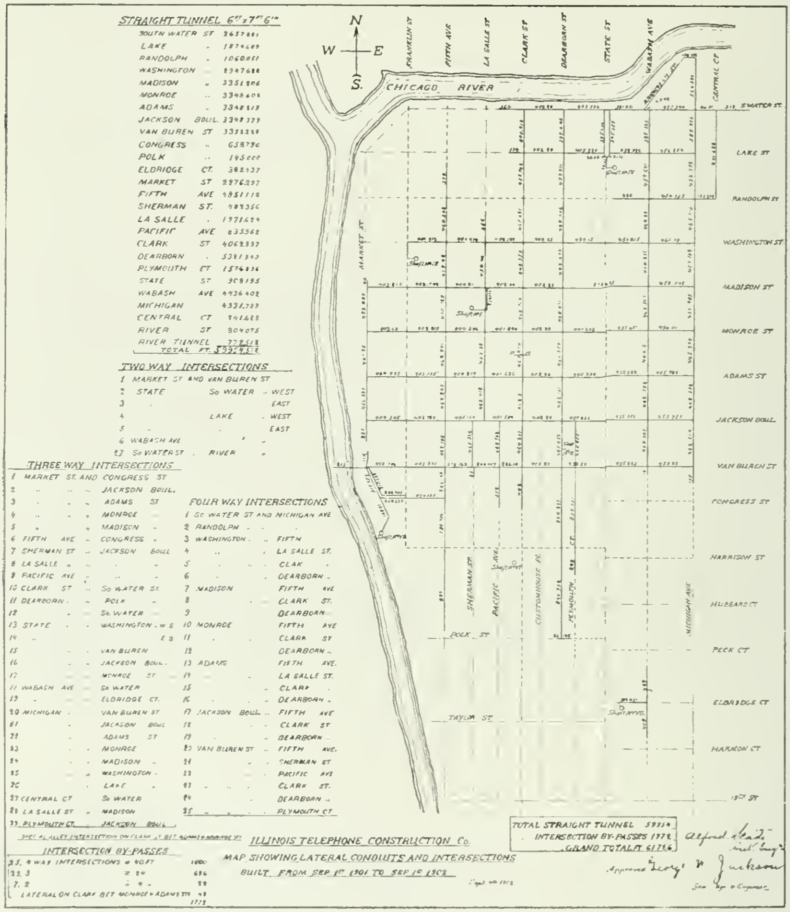


Fig. 16. Map and Quantities of Conduits Constructed up to Sept. 1, 1902.

Fig. 13 shows our method of movable platforms, which were

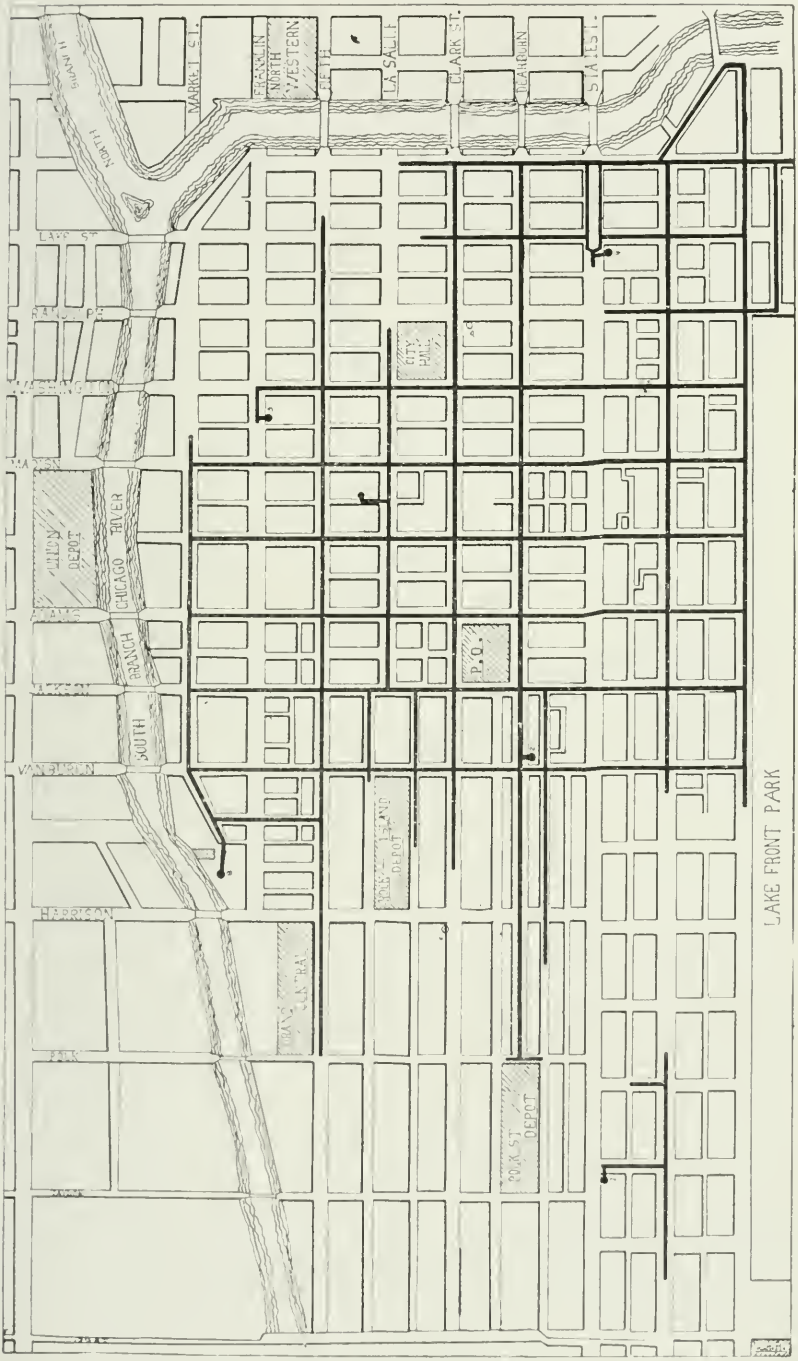


Fig. 17. Showing Conduits as Completed Sept. 1, 1902.

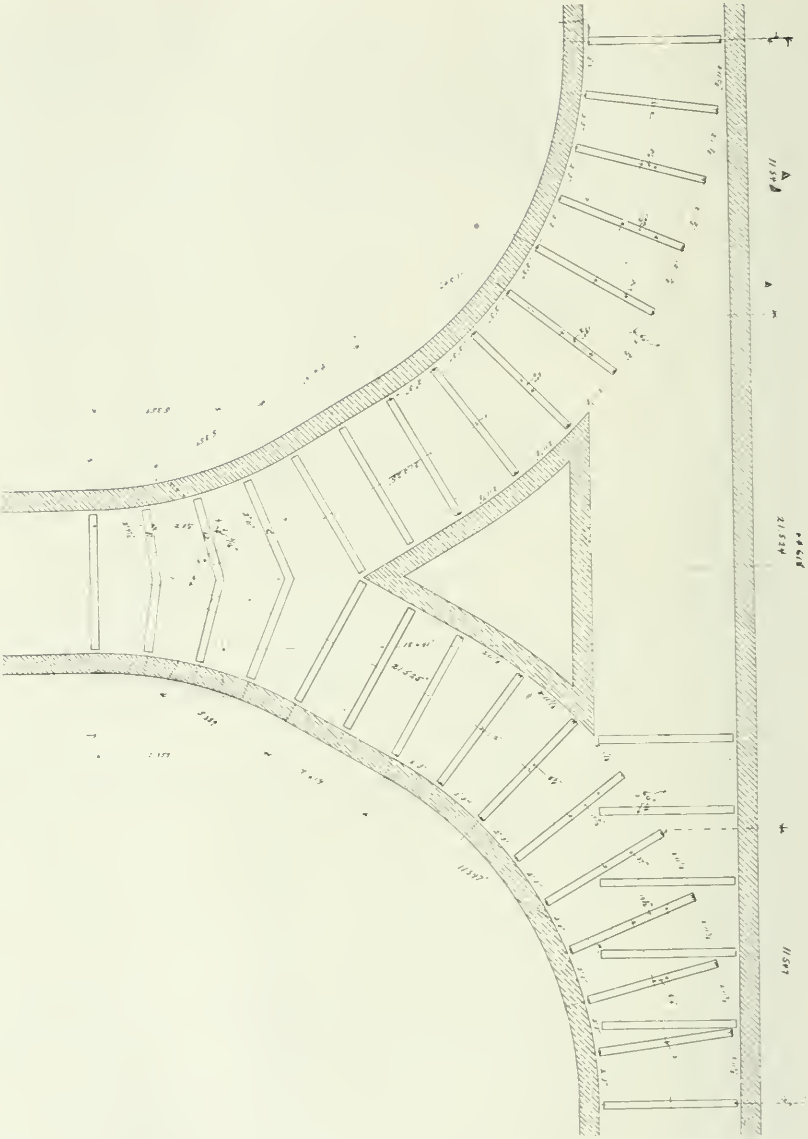
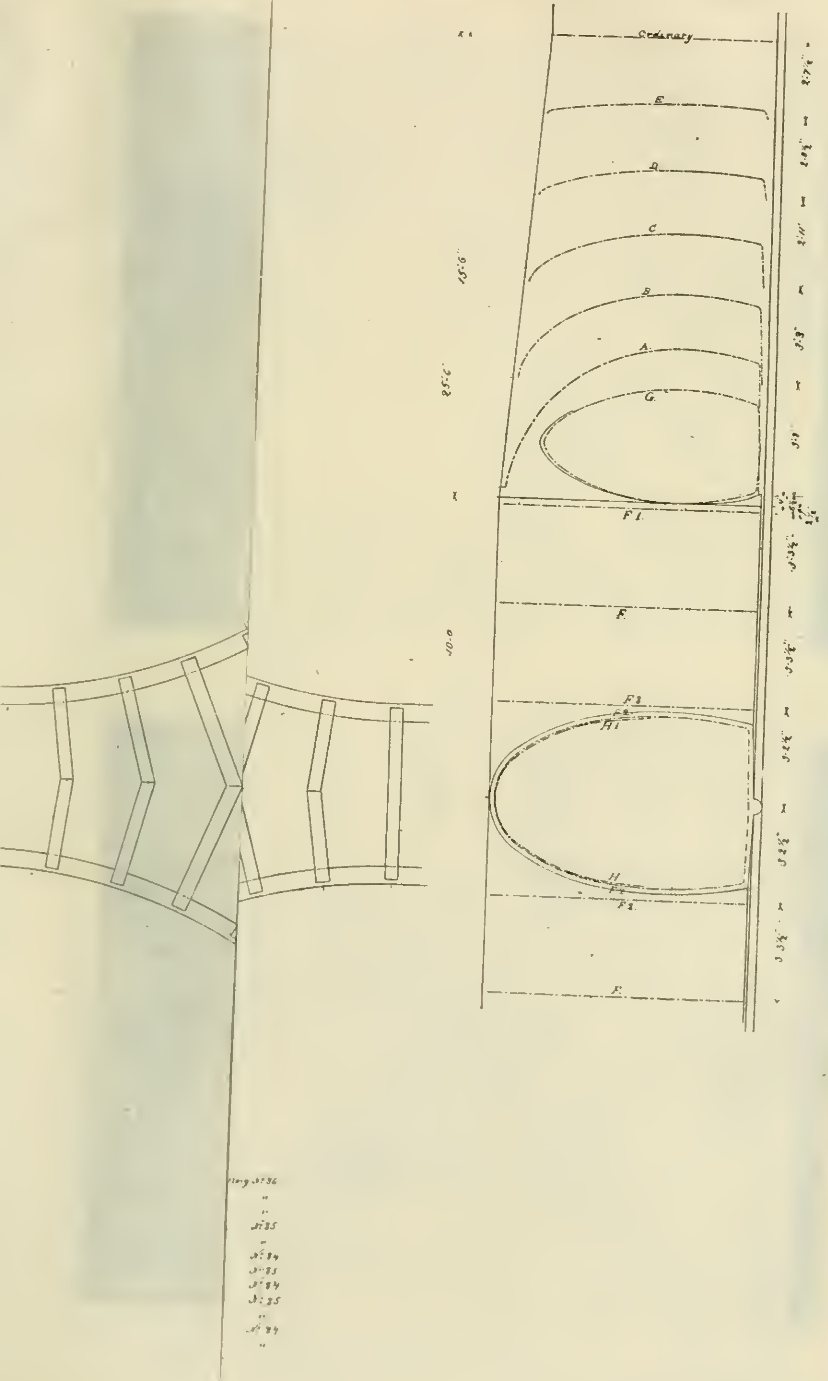
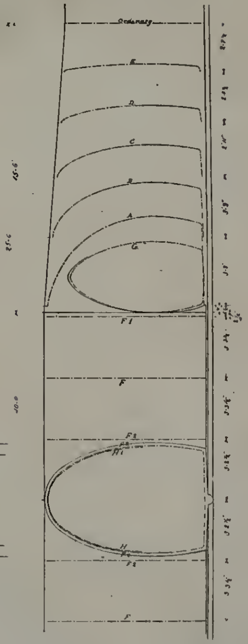


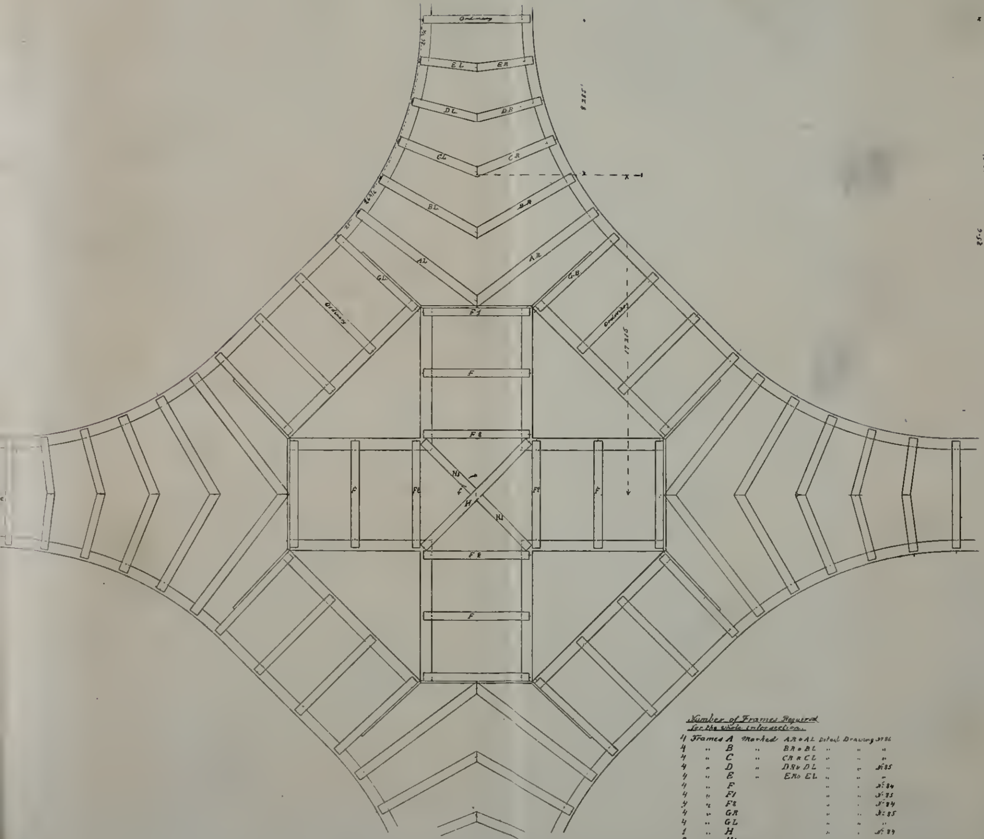
Fig. 13. Three-way Intersection. Location of Frames to Support the Lagging.

erected so that they could be raised or lowered and not interfere with boats going up and down the river when not in use. The next illustration, Fig. 14, shows the platforms being lowered down

Western Society of Engineers.
Vol. VII. No. 5.—Fig. 18.
Jackson—Telephone Tunnel Conduits.







Number of Frames Required
for the whole Intersection.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | Frames | A | Marked | AR & AL | Detail | Drawing | No 86 |
| 4 | " | B | " | BR & BL | " | " | " |
| 4 | " | C | " | CR & CL | " | " | " |
| 4 | " | D | " | DR & DL | " | " | No 85 |
| 4 | " | E | " | ER & EL | " | " | " |
| 4 | " | F | | | " | " | No 84 |
| 4 | " | F1 | | | " | " | No 85 |
| 4 | " | F2 | | | " | " | No 84 |
| 4 | " | GR | | | " | " | No 85 |
| 4 | " | GL | | | " | " | " |
| 1 | " | H | | | " | " | No 84 |
| 2 | " | H1 | | | " | " | " |

Fig. 19. Four-way Intersection, Showing Disposition of Frames for Lagging.

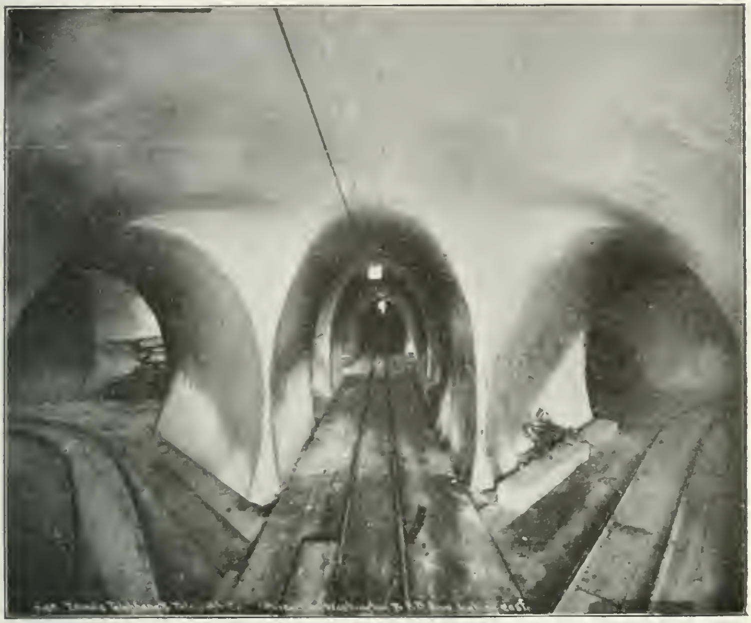


Fig. 20. Four-way Intersection Completed.

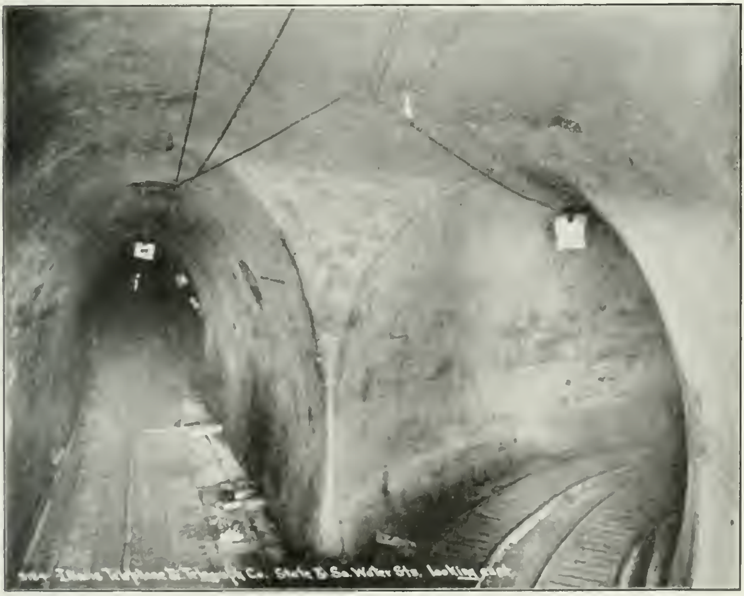


Fig. 21. Intersection at State and South Water Streets.

to the scow and the men about to dump the cars. This method of handling excavated material, was found to be very economical and did away with possible annoyance of delay, besides increasing the capacity of the tunnel to such an extent that no matter how many headings it was decided to operate, it enables us to do so.

The full-page illustration (Fig. 15) shows a map of the downtown district as designed to be built, with heavy lines for the trunk conduits and light lines for the laterals.

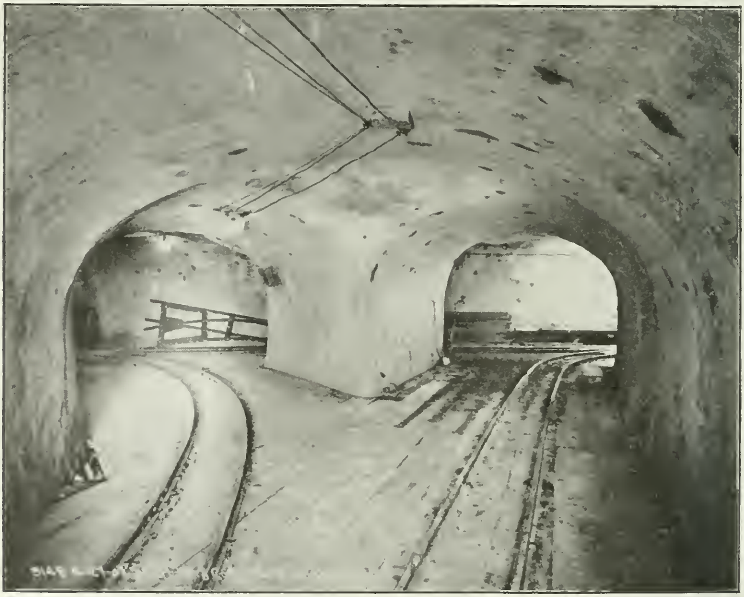


Fig. 22. Three-way Intersection at Congress and Franklin Streets.

Figs. 16 and 17 show maps of the tunnels as constructed at the present time, with a table of lengths, intersections, etc.

The illustration Fig. 18 shows our method of steel ribs and lagging used in the construction of what is known as a three-way intersection, while the inset, Fig. 19, illustrates the method used in the construction of four-way intersections, showing the placing of the ribs and lagging frames.

The next illustration (Fig. 20) shows the four-way intersection as built and located at Washington street and Fifth avenue looking east.

The illustration (Fig. 21) shows the intersection at State and South Water streets, and the illustration (Fig. 22) shows the three-way intersection at Congress and Franklin streets. This intersection was built larger for the purpose of having more room in handling material at Shaft No. 8. Its size is 7 feet by 8 feet.

The illustration Fig. 23 shows a straight piece of 6 feet by 7 feet 6 inches lateral conduit, ready for inspection.

I would like to add that in carrying out the construction of this twelve miles of work, we have not as yet had a single complaint from a taxpayer or a pedestrian on the streets, or a complaint from any department of the City Hall. Also that we have been very fortunate in not having an accident on the work. I would also like to add that the Department of Public Works in the City of Chicago,

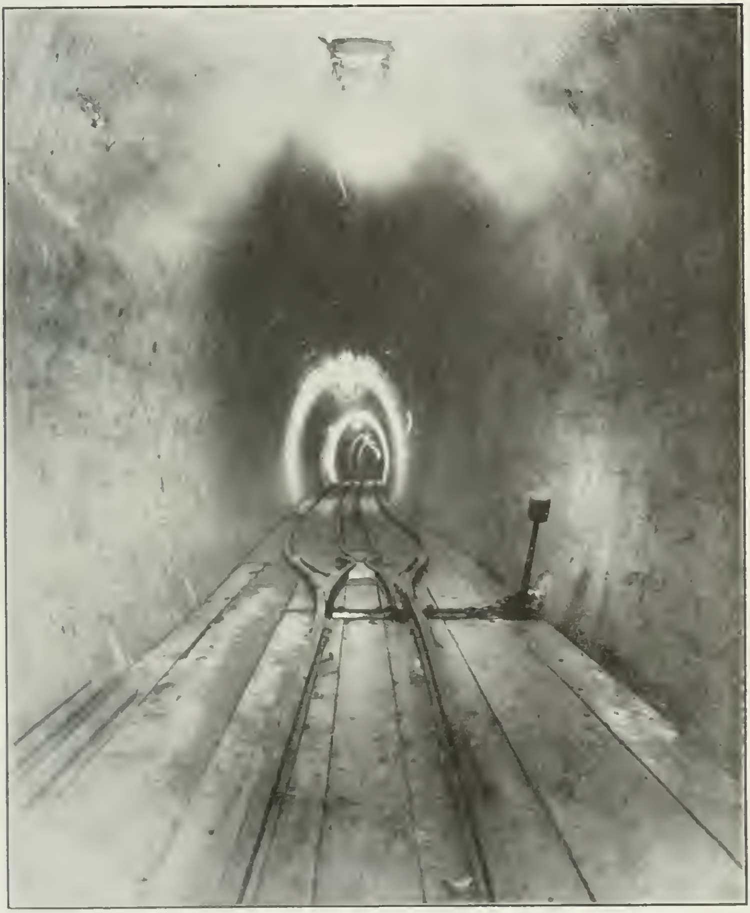


Fig. 23. View of 6x7½ ft. Lateral Conduit Completed and Ready for Inspection.

during the construction of the twelve miles of conduit, saw that the work was done in such a manner that there would be no possible chance of any criticism from taxpayers, they keeping almost hourly reports of the work as it progressed.

In conclusion, allow me to say that there is no doubt but that the people of Chicago will receive great benefit from the building of an exchange of 100,000 telephones, and I know it is the desire of the company to give them every benefit that can be derived therefrom. I also know that it is the desire of Mr. Wheeler, and the financial men interested with him, to have the good will of the people of Chicago and that it is to give our people the best telephone system in the world.

## DISCUSSION.

*Mr. L. P. Morehouse*—Did you mention when this work was begun?

*Mr. Jackson*—About a year ago, the 3rd of September, 1901. We were some little time making a new survey, as we found there was not in existence an accurate map of the streets.

*Mr. Warder*—As I understand it, you virtually built a mile a month.

*Mr. Jackson*—Yes, more than that—over twelve miles in about ten and a half months of actual work.

*Mr. W. S. Love*—How did you take care of the water?

*Mr. Jackson*—Fortunately we didn't have any. We are down some 18 feet below the lake. There isn't much water at that level, as it is a good, sound and firm clay.

*Mr. Jas. N. Hatch*—How many miles of conduit do you expect to build?

*Mr. Jackson*—About sixty.

*Mr. Ashley*—May I ask what thickness you mentioned for the concrete walls?

*Mr. Jackson*—The 6 foot by 7 foot 6 inch lateral conduits are constructed with 13 inch bottoms and 10 inch walls of concrete. The trunk system is constructed with 21 inch bottoms and 18 inch walls of concrete. And we carry from seven to nine pounds of air pressure,—but sometimes as low as five pounds. This is as a measure of precaution more than anything else.

*Mr. Hatch*—When the tunnel is finished what system of transportation will you have?

*Mr. Jackson*—We will use the trunk system for conveying our appliances and placing our cables.

*Mr. Hatch*—Electric cars I presume.

*Mr. Jackson*—No—regular cars, for carrying the reels of lead covered cables.

*Alderman Eidman*—Is your roof strong enough to carry the foundation of a future subway and a heavy rolling load?

*Mr. Jackson*—Yes, you could place the Auditorium on top of it and it would not disturb it any.

*A Member*—What provision is made for lateral connection with the subscriber?

*Mr. Jackson*—We drift from our tunnel; make a 3 foot drift, run up under the curb wall, or just inside, and then drive a pipe down—2, 3, 4 or 6 inch pipe—from the basement floor to the top of our 3 foot lateral drift. This provides for the disposition of the cables into the building for our customers.

*Mr. Hatch*—What provision have you made for circulation of air?

*Mr. Jackson*—One way, we expect to tap into some of the smoke stacks. This will be a benefit to them. The only trouble, there will be too much ventilation, and we will have to put on valves. There will be no objection on the part of the property owner, because it will be a benefit to his stack.

*Mr. Hatch*—Why cannot a subway go deeper than 19 feet? Would it undermine the foundation?

*Mr. Jackson*—I am afraid it would.

*Mr. Hatch*—Do you expect the ventilation will relieve the interior of dampness?

*Mr. Jackson*—It certainly would. We have a good deal of circulation as it is. The air from the outside will be drawn right through. There is no trouble from dampness now, and it is almost as dry there as it is in this room.

*Mr. Hatch*—Will you have a force of operators in the tunnel?

*Mr. Jackson*—Yes, to place the necssary cables and to make splices.

*Mr. Love*—All your concrete is mixed and made on the ground and then put in the cars is it not?

*Mr. Jackson*—Yes, on the ground floor of basements rented for that purpose, and then carried by our small cars to the heading, for use.

*Mr. L. E. Cooley*—Have you observed any objectionable effect of the compressed air on the setting of the cement?

*Mr. Jackson*—We get no bad results. If there was any chance of the air escaping through the clay, we might have some bad results. This has been demonstrated by carrying air under 9 pounds pressure on twelve miles of tunnels, with air compressors of less than 2,000 feet capacity.

*Mr. G. A. M. Liljencrantz*—In constructing the shaft, at what average distance below grade do you strike that clay?

*Mr. Jackson*—Going down from the grade here, one finds about 10½ feet of filling, below that point there are 18 inches of yellow loam containing a good deal of water; below that, about 5 feet of very soft clay; lower down you get into a harder clay. On the line of the city sewers there are 18 inches of a miserable loam; I say "miserable loam" from the fact that engineers and architects are not able to put any weight on it. The firm clay we encountered for the construction of these conduits is about 19 feet below the street grade.

## CLVI.

# THE AUTOMATIC TELEPHONE AND SWITCHBOARD.

By Messrs. A. E. Kieth and J. F. Crook.*

*Presented September 17, 1902.*

I appreciate this opportunity to bring before you, for your personal examination, the automatic apparatus with which the Illinois Telephone and Telegraph Company will equip its immense exchange in this city, the cables of which are to run through the great system of conduits which Mr. Jackson has so interestingly described to you this evening.

I would be glad to take you back to the earlier age of automatic telephony, and, beginning with the parent switch, a mechanical protoplasm as it were, show you the various stages which it has undergone to reach its present state of development; but you are more concerned with the developed mechanism, or perfected system. Suffice it to say that in spite of skepticism, or so-called conservatism, those who believed in the automatic system, and did not listen to their critics who declared it to be an ignis fatuus, have seen their fondest expectations realized; and even the prophets of failure are now admitting that the automatic telephone and switchboard are to revolutionionize the telephone industry.

Is it to be wondered at that, electricians seeing the automatic idea introduced with such success in other lines of progress should endeavor to apply it to the telephone exchange? The business man is no longer willing to idle his time away waiting for a tired or sleepy or indifferent girl at the central office to answer his signal and connect his telephone with that of the person desired. His business demands that he secure the party at once, and that when once secured no one shall overhear his conversation.

The system which I shall describe is the Strowger automatic telephone exchange system, the rights of which for the United States have been acquired by the Automatic Electric Company. The automatic telephone differs from the manual phone only in the dial which is on the front of the box, and the keyboard on the inside with which this dial is connected, as shown in Fig. 1 and 2. This dial has ten finger holes on its periphery, which are numbered from 1 to 0. By placing the finger in any of these holes the dial may be revolved until the finger reaches the stop placed below the dial. Any combination of figures can be made to make any number. A person calling 561 would first turn the dial by placing the finger in

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*After the reading of this paper, the working of this telephone system was explained by Mr. Kieth, by means of a model exchange with telephones connected up, temporarily installed in the Society's meeting room.

No. 5 and pulling it round to the stop. On releasing the dial it returns to its normal position, and the operation is repeated for No. 6 and then for No. 1. Each movement operates a switch at the exchange, and when the three movements are completed the connection with 561 is immediately secured, and by pressing the button just below the dial the bell of that telephone is rung.

The switches illustrated in Figs. 3 and 4 are devices about fourteen inches high and four inches wide, consisting of a number of relays, magnets and springs below which are the banks of contact points; the upper one called the "busy" bank, the other two the rotary and vertical banks. The upper half of the switch consists of six relays—which operate the selective parts of the lower half. The latter consists of three sets of banks of one hundred contacts each—one busy and two line banks. These are arranged in ten rows of ten contacts each, mounted on a semi-circular structure, the axis of which is a vertical selector rod, about ¼-inch diameter, upon which is fixed a contact arm about 1½ inches in length. The rod

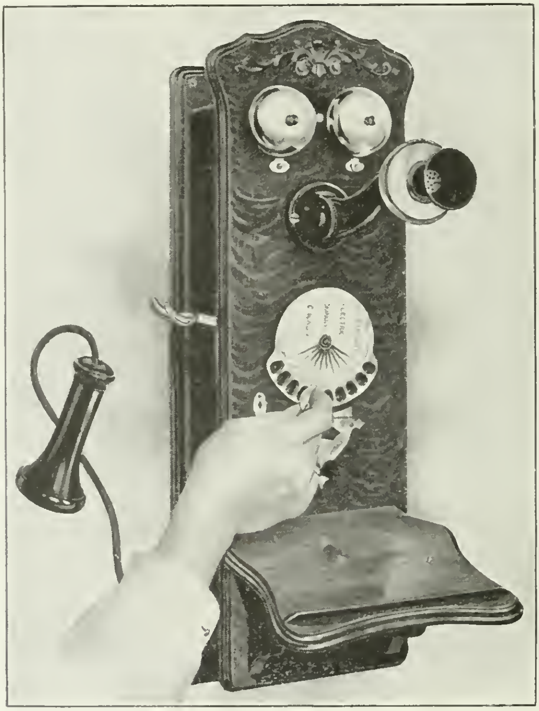

Fig. 1.

has both a vertical and rotary action, each controlled by one of the relay magnets above mentioned. When the subscriber calls 75, for instance, the rod is lifted vertically by the first movement of the subscriber's dial, which sends a current over one side of the two-wire circuit, thus raising the rod step by step to the seventh row of contacts. The second movement of the subscriber's dial sends the current over the other side of the circuit, and the controlling magnet gives the rotary motion to the rod which moves the contact arm to the fifth contact in the seventh row, thus securing the connection with 75. When the caller hangs up his receiver, current is sent over both wires of the circuit, releasing the selector rod, which then goes back to its normal position.

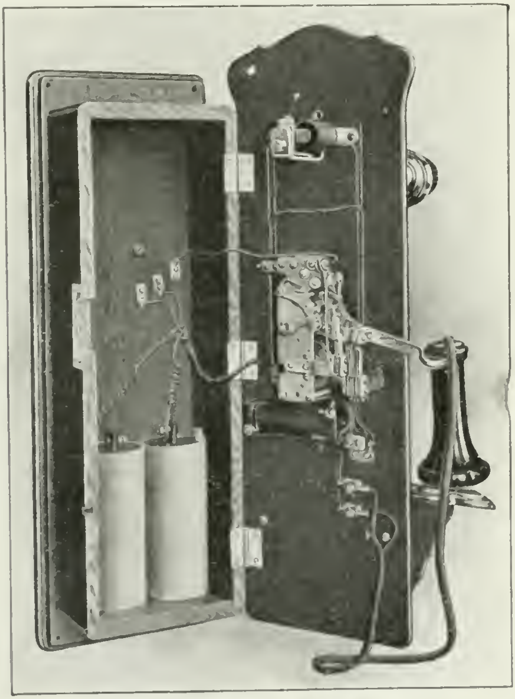

Fig 2

The lower part of each switch consists of three banks of contacts, the one mounted above the other, and held in place and secured to the superstructure of the switch by two $\frac{11}{32}$-inch steel rods, which pass through the steel binding plates at the top and bottom of each bank, and are fastened by four nuts. The uppermost bank is the "busy" bank and consists of one hundred spring brass contacts arranged in ten rows of ten contacts each, bound and held together by two steel plates, with screws and brass nuts. The insulation used consists of bond paper treated with linseed oil, with a fibre filling. This linseed oil paper has been found to be the best insulation as it requires 1,000 volts to break down a thickness of one-thousandth of an inch. The paper used in the manufacture of these banks is five-thousandths of an inch in thickness, and it would, therefore, require 5,000 volts to break it down. It is practically impossible, however, to break down this insulation as the paper is strengthened by a filling of hard fibre.

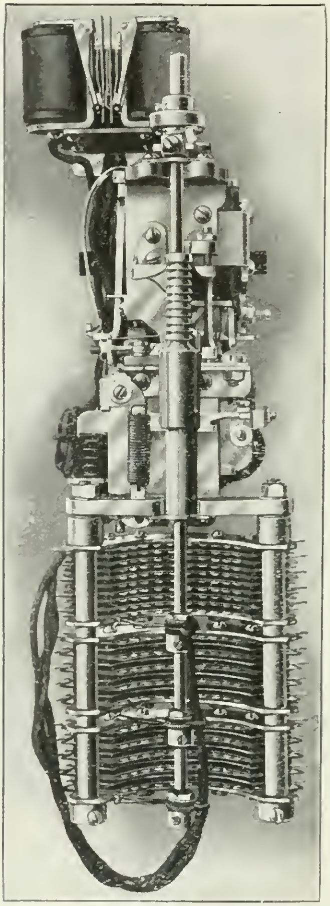

Fig 3. Front View.

The "vertical" and "rotary" banks are similar in structure, and consist of one hundred contacts, arranged in five rows of twenty contacts each. Each row consists of two layers of contacts, ten to the layer, the layers being separated by a specially treated insulating strip of extra fine fibre and linseed oil paper. Each of these banks is bound with the same size steel plates, screws, and nuts as those used in the "busy" bank. All banks are wired with No. 24—one cotton and two silk—beeswaxed and tinned switchboard wire. The vertical and rotary bank wires are twisted in pairs throughout the system.

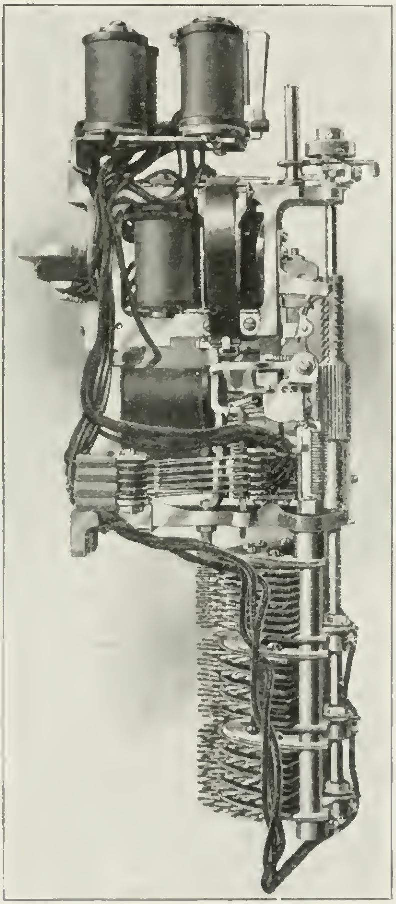

Fig. 4. Side View.

It is not my purpose to go too far into the explanation of the working of the system, but I desire to speak of the advantages which the automatic system offers to the telephone user, as well as to the exchange management.

First let me say that the life of this apparatus is longer than the best product of the manual telephone engineers. The numerous parts which cause much trouble in the manual exchange, such as jacks, plugs, cords, signal lights, etc., are unknown to the automatic system, and with their passing has gone a host of exchange troubles which constantly came up to plague the operator and the subscriber under the old regime.

In the second place, the automatic system is entirely, not partially, automatic, and the "hello girl" who has been the guardian spirit of the central office, and also of the secrets of the subscriber, is entirely done away with. With the passing of the telephone girl will also go a long train of delays and numerous annoyances to which the public has been subjected. I am aware of the fact that in thus heralding the retirement of the operator, I am doing violence to a sentiment which has often been paraded as a sort of scarecrow by those who view with alarm the improvement of machinery and its effect upon society in the way of decreasing opportunities for employment. Indeed I recall a pathetic bit of verse, written by a bright representative of the eastern press, when our apparatus in operation at Fall River and New Bedford, Mass., began to attract so much attention. However, he wrote his lay along entirely different lines, deploring the loss of a "bit of calico," as Opie Reed would say, to whose voice he listens at the telephone and whose image he fondly throws upon the retina of his imagination. He sang as follows:

A girlless telephone! Oh say,
Hello! Hello! how's this?
And can it be that we must come
At last, alas, to this?

A 'phone without a "hello girl,"
Would be a poor affair,
E'en though she ruffles us at times
And (almost) makes us swear.

Despite her faults we love to list
Unto her soft "hello,"
Then pity take ye men of wires,
Avert this final blow.

Don't rob us of the one bright ray
Amid life's telephonic whirl—
Take anything else you will, but spare,
Oh spare the "hello girl"

But we are ignoring sentiment and getting down to business. With no operators to "listen in" at the central office you can readily see that the automatic system offers to its subscribers a method of communication which is absolutely private. A method, in fact, by which a broker, wishing to call a patron, a physician a patient, a police official a policeman or detective, a merchant his salesman, or a man his wife or sweetheart, would feel perfectly secure in using.

Now a word in defense of the "hello girl," for turn about is fair play. She is not always to blame for delays and troubles. No two people use the telephone alike; no two articulate alike; comparatively few articulate well; therefore the girl is too often confused by the carlessness of the person calling, though she is obliged to bear the blame. Now the automatic system eliminates these troubles. The human voice is not used in securing a connection by the automatic route. It is a simple matter of revolving the dial the proper number of times and then pressing a button to ring the bell of the person desired. The calling subscriber becomes his own operator. He may get a connection as quickly as he desires, or he may take as long as he cares to do it, but any delays which may occur cannot be laid at the door of the "hello" girl.

In the event that the desired line is busy, a signal is automatically thrown upon the line of the person calling, which gives a vibratory sound in his receiver the "busy" signal. It may be said that where this signal is heard the line is positively busy, and the person getting it may rely upon its accuracy. I believe there may be some of you who have had a different experience in using the manual telephone.

In the use of the automatic telephone it is impossible for a third party calling to "cut in" upon two who are conversing. How many times have you, in the midst of a conversation, heard a sort of rattle in the receiver and then an ominous silence? Presently your bell rings and you are told by the person with whom you were conversing that "they cut us off," a bit of information of which you were already the angry possessor. The automatic switch is so arranged that when you once get a line it is yours exclusively, and all efforts to break in upon you are automatically side-tracked without a possibility of accomplishing their purpose.

It is not necessrry for me to dwell at length upon the great saving in the expense of exchange management effected by the automatic system. This is not only manifested in operator hire, but also in fuel, lights, rents and accommodations for the operators. The number of switchboard operators varies according to the number of calls sent through the exchange. In a small country exchange one operator could doubtless look after one hundred drops, but in such an exchange as that in the lower part of New York City an average of one operator is needed to every ten subscribers. Operators are paid from $5 to $10 per week, according to the location of the exchange, and wages would not be as high in a small as in a very large city. We may safely say that in an active exchange of of 2,000 lines fifty girls would be required, whereas in an automatic exchange of the same size only two switchboard attendants would be needed, their business being only to test the switches and keep them in order.

No matter how busy the automatic exchange may be, no increase in the number of attendants is required. The switches are always ready for action, whether midnight or midday, and no emergency can arise which cannot be handled. This is a manifest advantage over the manual exchange in which the number of operators is increased during the busy hours and decreased at night. A sudden influx of calls during the night hours, caused by some emergency or some event unlooked for by the management, often results in confusion and delay.

Trouble is easier to detect and remedy in the automatic exchange than in the manual. Every subscriber in the former has it in his power to notify the central office when any trouble occurs, either in his telephone or on his line, without having to go to another telephone to do so. In many cases these line and telephone troubles are automatically indicated at the central office and are corrected before the subscriber is aware of them.

In a very large system where it is necessary to have several exchanges the trunking between them is all automatically done. Trunk lines are picked out and subscribers in different exchanges are connected as rapidly as though their telephones were operated by the same switchboard.

One other feature upon which I should like to touch is this: There is a peculiar paradox in the telephone business of to-day, which may be stated as follows: The complexity of an exchange and the cost of service per subscriber increases much more rapidly than the increase in the number of subscribers. For instance, by the time every subscriber to an exchange of 500 lines has called up every other subscriber, 250,000 calls have been made. Increase the exchange to 1,000 lines, and by the time each subscriber has called every other, 1,000,000 calls have been made. Thus you have multiplied your capacity by two, but you have multiplied the number of possible calls by four. Your labor must be increased in proportion, and the wear and tear is likewise increased. This applies to the manual exchange. It does not apply to the automatic. In the latter system an increase of subscribers means a corresponding increase in the number of switches and telephones. The exchange of 10,000 lines is no more complicated than one of 2,000, and it costs no more per subscriber to give good service in the former than in the latter.

A full metallic circuit is required for the operation of the automatic exchange, the same as is used in all modern manual exchanges, two wires being run from each telephone to the central office, and the power is furnished by 50-volt storage batteries which may be charged from a direct current wire.

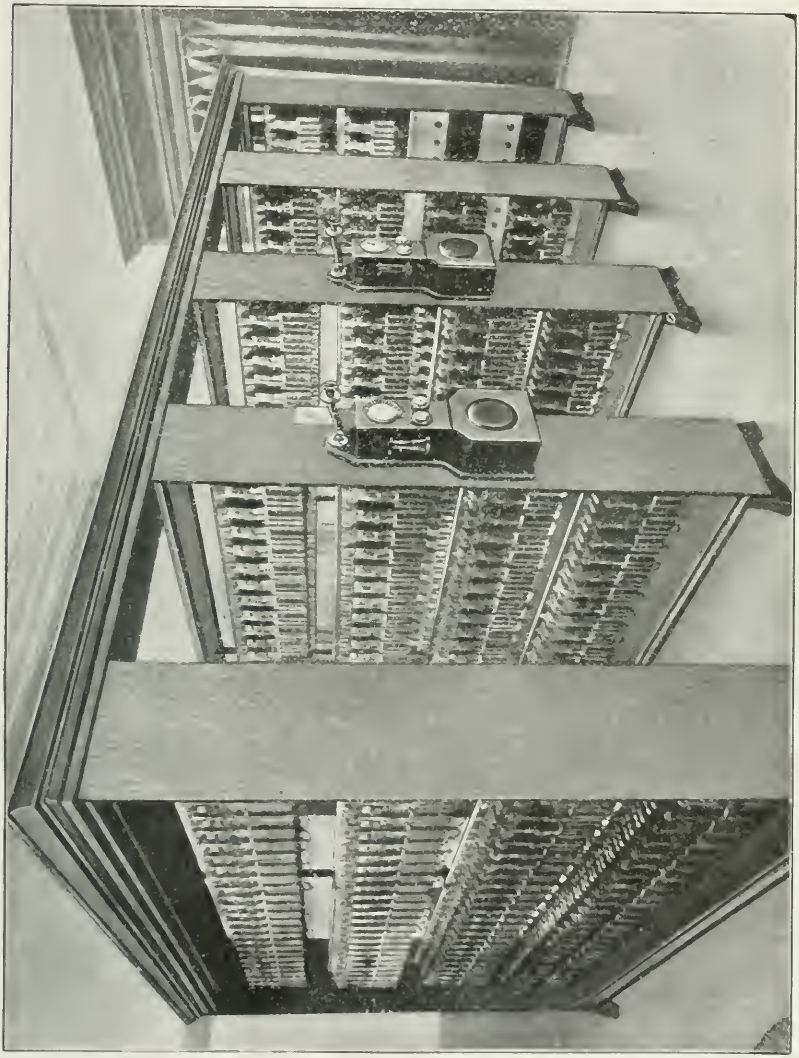

Fig. 5. Automatic Exchange, Berlin, Germany.

The German government adopted the automatic system after the American company had built an exchange of 400 stations (Fig. 5) in

Berlin, and it had been operated for more than a year under the auspices of German telephone engineers. So satisfactory was its work that the exchange was purchased and made a part of the Imperial Postal Department.

The construction and successful operation of the exchanges at Fall River and New Bedford, Mass., each of which has an ultimate capacity of 10,000 lines, opened the eyes of the world to the new system of telephony. I might say that they ushered in a new era. No one, be he expert or layman, can visit these New England exchanges and not be charmed by the rapidity and precision of the service, and the universal satisfaction it is giving. It remained for conservative New England, as we in the west often call her, to adopt this new idea for large exchanges, and show its merits to the world. In the Fall River automatic exchange, where there are more than 900 telephones working in a system, the ultimate capacity of which is 10,000, the exchange has been locked up for hours at a time, and, without any attention whatever, it has done the work of the subscribers in that busy New England city. This view gives a very good idea of the appearance of an automatic exchange.

The Automatic Electric Company, manufacturer of these exchanges, is now building exchanges for the cities of Dayton and Columbus, Ohio, each of which will have an ultimate capacity of 19,000 subscribers. The Dayton company will begin business with 6,000 stations. The Columbus company will have 7,000 connected up at first. The latter company discards a manual board which was built less than three years ago, at great expense, in order to install the automatic system. We do not think that more convincing proof could be given than the action of the Columbus management.

Here in Chicago the Illinois Telephone and Telegraph Company will install a system to ultimately take care of 100,000 lines. Twenty-five thousand switches will be mounted and connected up at an early date in the down-town district, and I think the company's expectations of a phenomenal growth will be more than justified as soon as the public is acquainted with the operation of its exchange.

JOHN BUTLER JOHNSON.

## IN MEMORIAM.*

Professor John Butler Johnson was born near Marlboro, Stark County, Ohio, June 11th, 1850, and died as the result of an accident at his summer home at Pier Cove, Michigan, on the east shore of Lake Michigan, June 23rd, 1902.

He was born of Quaker parentage on a farm and attended school at Marlboro until sixteen years of age, the last year being at the high school of which Dr. T. C. Mendenhall was then the principal. From 1868 to 1872 he taught school in Indiana and Arkansas, and in 1872 went to Indianapolis as Secretary of the School Board. He also taught one year in the Indianapolis High School, where he was required to teach Latin, although never having studied Latin himself. On several other occasions in his career he had been called upon and did teach subjects which he had never before studied, which led one of his associates to remark that "Johnson could teach all he knew and more."

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*Prepared by Messrs. O. C. Simonds, C. W. Melcher, T. L. Condron and J. W. Schaub, Members, W. S. E.

In 1874 he entered the University of Michigan at Ann Arbor, where he was graduated in 1878 from the course of Civil Engineering. From 1878 to 1881 he was engaged on a survey of the Great Lakes, and from 1881 to 1883 he was Assistant Engineer of the Mississippi River Commission.

In the Fall of 1883 he returned to the profession of teaching, having been elected to the chair of Civil Engineering in Washington University at St. Louis, where he remained until called to be the Dean of the Engineering School of the University of Wisconsin in January, 1899, which latter position he held when he met his untimely death.

It is appropriate to add to this brief outline of his engagements, something more regarding the work he accomplished during his lifetime after entering the engineering profession in 1878. About his earliest work of importance was in 1882, when he was commissioned to measure the discharge through various crevasses, during the spring flood on the lower Mississippi, which work led him to recommend several improvements in the work of river control, the wisdom of which has since been realized. He also made a thorough investigation into the errors involved in precise leveling, and evolved a method of conducting such work that has since been widely adopted.

Of his work at Washington University, Dr. C. M. Woodward has written as follows:

> "As a teacher Professor Johnson was sympathetic, painstaking, progressive, and very thorough. He was never content with what he did last year. He never found it possible to repeat an old lecture. Study and experience added constantly to his value, and his students are most emphatic in their praise of his influence upon their lives, both technically and morally. The 'Professor' had a wholesome disrespect for mere authority. His mind was preeminently free from prejudice and always rational. He was a hard worker and his students learned to work hard with him. Whether in the classroom or in the field, he was indefatigable."

During the years he was in Washington University, he found time to render what has been his greatest service to the profession, in preparing and publishing four important books. The first of these was "The Theory and Practice of Surveying," published in 1886, which has now passed through a dozen editions and frequent revisions. He said he was forced to write this book in order to teach surveying to his classes, as he found no satisfactory text-book published on this subject. This book was at first intended only for use in his own classes.

The second book he published, "The Theory and Practice of Modern Framed Structures," (1892) was the joint product of Prof.

Johnson, Prof. F. E. Turneaure, and Mr. C. W. Bryan, and, like its predecessor it has required several editions to meet the demands of engineers and engineering schools.

In addition to these books, his "Engineering Contracts and Specifications," published in 1895, and his "Materials of Construction," published in 1897, have both been received with great favor by engineers in all branches of the profession. Of the work upon the "Index to Current Engineering Literature," which he directed and largely carried on personally, he says in the preface to the volume covering the seven years from 1884 to 1891: "If the volume now put forth should contribute somewhat to the cause of good engineering in America, those to whom its usefulness is due, will feel fully repaid for what has been largely a labor of love."

From 1892 to 1895 he was engaged in making investigations into the strength of timber for the Division of Forestry, U. S. Department of Agriculture. The very extensive and thorough series of tests being made under his direction in the testing laboratory of Washington University. These investigations have been of great value to engineers and builders, one of the principal results being the marketing of "bled" timber, which had been previously regarded as practically worthless, thus appreciating the value of timber lands many millions of dollars.

Of his work at the University of Wisconsin, Acting President Birge has written as follows:

> "Much as Dean Johnson had accomplished during his three years' stay at the University of Wisconsin, the promise of his work for the future was so much larger than the performance could possibly be at the date of his death, that it is peculiarly difficult to sum up his work and his influence in the University. The College of Engineering grew very slowly during the earlier years of its history, but in the years preceding Dean Johnson's coming, had been growing rapidly, and developing an organization and an *esprit de corps* of its own; yet in the absence of a regular head, this development was necessarily more or less partial. When he came, therefore, he found a college strong and growing, conscious of its own possibilities and eager to realize them. It was, I think, his supreme merit to have recognized this situation, and adapted himself to it, catching quickly and fully the spirit and temper of the college to which he came; modifying it by his own personality, yet always remaining in full sympathy with it. Dean Johnson was a man of restless intellectual activity, capable of leading his college, full of plans for its development, hopeful—even sanguine—of their success, ready to try experiments and eager to push the college forward in every way. With all these gifts for leadership, however, he did not separate himself from his colleagues in the faculty, but succeeded to a very unusual degree in making himself the center, as well as the leader, of his college. He won the affectionate and enthusiastic regard of the students, so that in a surprisingly short time he made himself, in the best sense of the word, the head of the College of Engineering in all its departments. The number of students increased greatly during his administration, and much of this increase was due to the prominence which his presence in the faculty brought to

the college. The building for the College of Engineering stands as perhaps the best material memorial of his work with us. To his wisdom and skill are due, in great measure, the unusual excellence and convenience of the building The rapid increase of the equipment of the engineering laboratories was brought about in a large degree by his influence. While his presence and work were in the highest degree helpful, and even indispensable to this material advancement and improvement of the college, yet these results do not at all adequately represent the real measure of his service to the institution. That service is best found in the spirit and temper of the college, in the development of higher ideals in its faculty and students, in larger plans for its advancement and their vigorous execution, in the presence of a stronger and purer *esprit de corps*among all the members of the college, whether student or faculty, and in the broadening and liberalizing of the spirit of engineering education as represented in the college."

During his short residence in Madison, Prof. Johnson became a prominent factor in the community outside of the University. He aided the city with his best counsel in municipal matters where engineering experience was of value, and engaged in active work in the church with which he was connected. In these directions, as in all others, he aimed to be of the most service to his fellows, and the universal sense of the great loss which his death has brought to the community as well as to the University, is the best witness to his high success in these efforts.

The Engineering News, in commenting upon his life and work, has said:

"While Prof. Johnson's professional reputation rests mainly on his contributions to technical literature, his work as a teacher of engineering held ever first place in his heart. He was deeply and sincerely interested in the work of technical education. His study of the German monotechnic schools, and his practical work in extending the benefits of technical training by the establishment of summer courses of study are recent illustrations of his constant activity in enlarging the scope and bettering the work of American technical education.

"The two books by Prof. Johson, on which his fame will most largely rest, are undoubtedly his 'Theory and Practice of Surveying' and 'Modern Framed Structures.' Both of these works met a real need in the profession, as their extensive sale proves. His 'Materials of Construction' and 'Engineering Contracts and Specifications' have also had a wide circulation. The two first named books, however, reveal their author as a practical engineer, as well as a competent text book writer; and while not a few teachers of engineering and writers of text books upon it would find it hard to obtain a certificate of practical competency, certainly none would accuse Prof. Johnson of being a mere theorist on any subject he undertook to discuss.

"It was his task as an engineer not to rear great bridges or perfect intricate machinery, but to make it possible for other men to achieve such things. All his work was indeed in the best sense, a labor of love, and it was because of his love for it, and the interest and enthusiasm which he brought to it, that it was in so large a degree successful. 'The cause of good engineering in America;' that was the cause in which John Butler Johnson's life was spent, and it is no small debt that the engineering profession owes to him."

Prof. Johnson was elected a member of the Western Society of Engineers March 14th, 1899. The following October the Society was invited by the President and Board of Regents of the University of Wisconsin to visit the University at the time of his inauguration as Dean of the School of Mechanics and Engineering. On this occasion, Prof. Johnson delivered an address upon "Some Unrecognized Functions of our State Universities." * In May, 1900, he read before the Society a paper describing the new Engineering Building of the University of Wisconsin.† Besides these two papers he contributed to the discussions of several papers before the Society.

He was also a member of the following societies, etc.: The American Society of Civil Engineers; the American Society of Mechanical Engineers; Institution of Civil Engineers (Great Britain); the International Association for Testing Materials; the American Society for Advancement of Science; the Engineers' Club of St. Louis; the St. Louis Railway Club; the Art Club of Madison; the Science Club of the University of Wisconsin, and the University Co-operative Association.

It seems to be peculiarly appropriate to close this Memorial of our late associate with the following address delivered by him before the meeting of Cemetery Superintendents in St. Louis some years ago, on the subject of: "A More Rational View of Death."

## A MORE RATIONAL VIEW OF DEATH.

As a layman, speaking to those whose professional employment consists in providing and maintaining beautiful resting places for our beloved dead, I have chosen to speak to you by way of encouraging a more cheerful and rational view of death itself. If we can succeed in looking upon death as a friend, as Daniel French has so beautifully portrayed in his memorial tablet to the young artist Milmore, now set in bronze in Forest Hill cemetery, near Boston, and will generally admit that death is not inherently an evil, but next to life itself the greatest earthly blessing, then we might hope to maintain towards it a more cheerful and reasonable bearing. And this is the thesis I have assigned myself in this paper.

To appreciate the changed attitude of the world in this matter, and especially with reference to burial places, we should note at least three periods of the world's history in this respect.

The oldest form of worship was that of deceased ancestors whose spirits were supposed to forever haunt the ancient hearth-stone and tomb, which were always near together. The maintenance of a perpetual fire on the one, and the proper attention and care of the other kept the descendants rooted to the home of their fathers, and gave to these resting places of the dead a sacredness and inviolableness which has always characterized these spots in all nations, and in diminishing degrees even to the present day.

Following this came the doctrine of the physical resurrection of the dead to an endless life, which was thought to have been the original attribute of the race,

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* Published in JOURNAL OF THE WESTERN SOCIETY OF ENGINEERS, October, 1899.

† Published in JOURNAL OF THE WESTERN SOCIETY OF ENGINEERS, June, 1900.

and which was lost through the sins of our first parents, which doctrine still finds adherents amongst the less educated and less thoughtful classes, and at one time pervaded all Christendom. This doctrine added, if possible, to the sacredness of the body from which all life had departed, and made its perpetual preservation a thing altogether to be desired and a filial duty which was fulfilled as far as possible. This necessitated a place of repose, pending this wonderful awakening, which should be sacredly preserved in undisturbed entirety from age to age until the resurrection morn, when Gabriel's trumpet should sound and these innumerable graves should render up their long-cherished and unviolated dead.

The present scientific age has dispelled both of these doctrines as tender illusions, for which the wish had been father to the thought. We have now ceased to regard the remains of our deceased friends as having any particular significance except as reminders of their living counterparts, and hence the preserving care of, and superstitious regard for these perishing, lifeless organisms, which formerly was a sacred duty, has now become merely a traditional and an entirely irrational custom. It is to be hoped the day is not far distant when cremation, the only rational disposition of the lifeless body, will be universally adopted in all civilized communities.

Another beneficent result of the more general prevalence of scientific knowledge is that the laws of this present world are coming to be better understood and accepted as wise and good. It was no meaningless or flippant remark of Margaret Fuller's when she said, "I accept the universe." For ages it has been considered the righteous thing to reject this visible, objective universe as a miserable failure, a vale of tears, a kind of way station where we are forced to tarry for a time in painful preparation for an endless existence in some other world, in which perpetual happiness and joy, or endless woe and torment were supposed to be prepared for all comers.

Now, I do not care, as a scientific man, to commit myself for or against any theory of a future life, for the truth or falsity of which I have no sufficient evidence to enable me to formulate an opinion, but the absence of any decided views on this subject does not trouble me in the least, as I once supposed it would. What I cannot know I cannot be accountable for, and hence I choose to shape my course, and would wish all others to do the same, in accordance with the knowable things of this world rather than the unknowable, feeling satisfied that whatever the future has in store "no evil can happen to a good man in life or in death."

Assuming, therefore, that we may look upon death as a product of natural causes, the same as any other natural phenomenon, and that these causes are found in the fixed, and as we believe the beneficent, laws of the universe, let us examine into it as we would into any other aspect of the workings of nature's laws, to see whether or not it is the hideous monster it is commonly represented.

First we must remember that we must view it as a whole, and not simply in its exceptional or most painful examples. Like any other law, if the conditions of its operation are complied with it must of necessity operate, whether its action is beneficent or injurious. So with fire, which was regarded by the ancient Greeks as the greatest gift of the gods to man, and yet it may be his most destructive enemy. In fact every law of nature, of which man has learned, may work evil as well as good if its operating conditions are ignored, and yet we call them all wise and beneficent, and thereby we accept the universe, with death included, as a good and wholesome world, when properly understood.

Probably the great argument in favor of death as a law of the universe, is that hereby only can the race make progress. With the ancient belief in a golden age when man was perfect and immortal, no improvement was possible and hence death was not a necessary condition, but with the newer and now prevalent view of the evolution of the human species, progress can only come with infinitesimal gains from generation to generation and all our superiority to our less progressive "poor relations" lies in this evolution through innumerable births and deaths.

Prof. Fiske finds a very strong support in this doctrine of the "ascent of man" in the long period of infancy of the human species. How much this developing period of childhood is fostered and stimulated by the fear of the death of the child on the part of the parent, he does not indicate, but if death did not exist we can all see how much this developing care of parents would be relaxed, and how the race might at once begin to degenerate. If death is then an essential condition of human progress, it must be pronounced good and not evil, and it is therefore a friend and not an enemy of mankind.

The subjective effect of this law on the individual is also most wholesome, when it is not regarded as an evidence of divine wrath or displeasure, or of an incomprehensible caprice. Remove it from the category of special providences, and it can be calmly viewed as the working out of the effects of natural causes. It must be regarded at times, however, as an unfortunate, sad, and pitiful result of the operation of a most beneficent law. These are the cases of "untimely death," to overcome which but stimulates the race, and which are rapidly being eliminated with the progress of science and the spread of its teachings. Even here death must still be regarded as the unexpected visit of a friend, and not as the stealthy stroke of an enemy. If we would all conscientiously contemplate the friendliness of death, not viewing it with fear and trembling as the great arch enemy of mankind, and as meanly stealing upon us as a thief in the night, but as coming quietly and in the most friendly and helpful way, leading us into the great unknown from which we have nothing to fear if we are not afraid to *live*, then we would not only welcome it when it comes to us, but we would regard the vanishing from mortal sight of our friends with a greater resignation and comfort As a friend goes to a far country to live, as a loved daughter marries and leaves the home of her parents, as a child goes from its home to be educated, so should the bearing away of our loved ones by death be regarded.

Yes, in some respects we may say this last journey has its consolations which the others lack. We all admit there are many things more to be dreaded than death, and so long as we live some of these may possibly come to us, but when our dear ones are once confided to the care of this last friend, we are certain no further harm can come to them.

It is one of the unaccountable facts that while death has always been so feared and dreaded by the well, it seems to be always welcomed by the dying The friendship for this unseen visitor then manifests itself, on the part of the passing spirit, and why then should we not also call Death our Friend? Surely, in a very true sense, those departed souls are nearer to us after this vanishing from outward sight than when clothed in flesh and blood. Proximity of body is no proof of commingling spirits. When the outward body has passed away then we feel that we can possess our friend entire, and our spiritual communion with the ideal and real friend is perfect and continuous, and nothing can now occur to break this perpetual bond and shaping influence.

The ever-present knowledge that death will come to us sooner or later is probably the greatest of all stimulants to noble endeavor Were we certain of a continuous existence here we would always be inclined to delay action and await the development of events. As it is, we feel that no time must be lost or wasted—that the present is all that we are sure of, and that every passing moment must be consciously utilized to help complete the work of a life known to be short, and which may end at any moment. We are thus changed from indifferent drones to working members of the human hive, with the result that our own and future generations will receive some good thing or some added pleasure as a result of our having lived at all.

We also thus develop our own personality, and if an immortal existence awaits us when the friend of all mankind calls upon us, we will be certain to receive in some form a further reward for our faithful services here. The blessings of death are therefore constant and perpetual, both here and hereafter, and if occasionally a few times in every life we are thereby stricken down by grief, and a sense of loneliness and loss almost overcomes us, we should be reasonable and remember all the benefits we and the world derive from this same Friend, who will one day call in turn for us.

Although it often seems as though lives were cut short in the midst of their allotted tasks, leaving them uncompleted, yet often the real benefit of a life comes only after it has ceased to exist. Then it is that the character wrought out in life is distilled into a spiritual influence which may accompany, pervade, and shape a thousand lives, as could not have been done by the embodied soul. If a feeling of incompleteness accompanies this influence, a thousand minds are stimulated to carry on what one had begun, and so the work grows and spreads by the death of its originator, as Christianity itself did when its founder was called away before his work had scarcely begun.

Then why should an air of gloom, of mourning, of sombre sadness pervade everything connected with death and the grave? Surely the dead are not honored in this despairing inaction. We honor them most by cheerfully lending a hand to complete the work they had begun, and to fill the void their departure had left in our midst. In this way we too may worship our ancestors, and to a much greater profit than in caring for their tombs and in ministering to the supposed wants of their departed spirits. Other losses are not to be repaired by mourning over them, then why should this be any exception to our common rule of conduct? There is but one answer to this question. It has become so fixed and universal a custom to do so that we should be considered heartless to abstain. To be strictly honest, one must admit, I think, that this is the case. No customs are so hard to change as those relating to death and burial In these respects we are still in the barbarous stage. In these affairs, most pre-eminently matters of the heart, of private or individual concern, we act as though we took council only of public opinion and had no personal interest in the subject. We either affect a sadness and grief we do not feel, or we coarsely parade before the gaping crowd our crushed and bleeding heart strings. In other matters of the heart we maintain our privacy intact from our nearest and dearest friends as modesty and delicacy, and a due regard for our own self-respect require, but in all matters relating to death in the family, the conduct of funerals, and our mourning habits, we are bound absolutely to a series of customs at once irrational, barbarous and oppressive.

But, you may say, why should we be told again of these things which we all know and have long deprecated? I don't know that I can give you a good reason, and probably I should apologize to you for bewailing before you a state of things you would all gladly join with me or any one else in correcting. Perhaps it is because I have felt that you as a class of men, charged with caring for our places of the dead, may possibly do a little to impress upon the public, in an unconscious way perhaps, the feeling that death is a friend and not an enemy.

I believe, however, you are all trying to do this. I am sure it is not with your approbation or advice that our cemeteries look so much like charnel houses. You surely do not favor bedecking them with broken shafts, ghastly marbles, and weeping willows. On the other hand, I am sure you are doing all you can to banish these from our "Cities of the Dead," as they are now very properly called, and to bring in the place of these emblems of sorrow the brightest of flowers and the most cheerful foliage; the most beautiful and inspiring trees and the most restful and inviting landscapes; and in place of iron fences and stone vaults give us glassy waters and shady walks. Give nature a chance to cheer and sooth the disconsolate and wounded hearts which venture here to be again near the remains of their loved ones instead of wounding and crushing them anew with skulls and cross-bones, lifeless marbles and ghastly sepulchres.

What I wish to see, therefore, in all matters pertaining to the final departure of the visible forms of our friends from this world is a general recognition of the following facts:

1. That all people should try to add to our common happiness, improvement and good cheer, feeling sure that the more we succeed in bringing heavenly happiness into this world the more likely we are to find a happy heaven in the next.

2. That death is the great friend and benefactor of the race.

3. That it comes only in accordance with the working out of wise and beneficent laws, and never as a special judgment, or by accident or through blind caprice.

4. That it should be received and respected as a friend and not reviled and hated as the insidious skulking foe of all mankind.

5. That all matters connected with death and burial should receive a more private, and therefore natural and cheerful treatment.

6. That the minds of those who mourn should be turned to the future rather than to the past, since looking backward, except to range a course forward, is always profitless.

7. That the lifeless bodies once inhabited by our friends should be reduced to their earthly elements in the most rapid and harmless manner possible.

8. That if these material remains are preserved in the bosom of Mother Earth, it be in spots unobtrusively marked in beautiful parks, where earth and sky, flower and foliage, lawn and lake, birds and butterflies shall each and all bring healing and joy to the crushed and bleeding hearts which will resort thither as a thirsty traveler to rippling waters

## DANKMAR ADLER.

### IN MEMORIAM.

Dankmar Adler was born July 3rd, 1844, in Lengsfeld, in Saxe Weimar Eisenach, Germany, where his father was a teacher in the public schools. He came with his family to America in 1854 and settled in Detroit, coming to Chicago in 1861. He attended the high schools at Detroit and Ann Arbor, and soon after leaving school entered the office of Mr. John Schaefer, a Detroit architect, and was afterwards employed in the office of Mr. E. Willard Smith, also of Detroit. After the family moved to Chicago he spent a short time in the office of Mr. Augustus Bauer.

In July, 1862, he enlisted in the 1st Illinois Light Artillery and served throughout the war. During the last nine months he was in the service he was employed as a draughtsman in the topograpical engineer's office of the Military Division of Tennessee, where his service was in great part a continued apprenticeship to his profession.

Upon his return to Chicago he became a draughtsman and afterwards foreman in the office of Mr. O. S. Kinney. In July, 1871, he formed a partnership with Mr. Edward Burling which lasted until 1879. As a member of this firm Mr. Adler had a large share of the reconstruction of Chicago after the fire, and practically rebuilt Lake and Randolph streets. Upon the dissolution of this partnership, Mr. Adler became the architect of the Central Music Hall, and this building brought him such an increase of work that in 1880 he took into partnership his chief draughtsman, thus forming the firm of Adler & Sullivan, who were the architects of the Auditorium. They were also the architects of the Schiller Building, the Chicago Stock Exchange, the Transportation Building of the Columbian Exhibition, the Union Trust and Wainwright Buildings at St. Louis, and the Guarantee Building of Buffalo, and many others.

After the dissolution of the firm of Adler & Sullivan, in 1895, Mr. Adler continued to practice architecture, but confined his work mainly to buildings where the construction and engineering were the main features. He was frequently called out of the city as Consulting Engineer on questions of construction and foundations, having been called to New York, Minneapolis, St. Louis and other cities for this purpose. Mr. Adler appreciated and paid particular attention to the engineering features of architectural work, not only in matters of construction but in those of equipment, and in April 1898, he read before the Western Society of Engineers an interesting paper on "Mechanical Plants of Large Buildings."

He was a member of the Illinois Chapter of the American Institute of Architects, and one of the originators of the Western Association of Architects, of which he served as President and as Secretary. He was also Chairman of the Illinois State Board of Examiners of Architects, and was influential in organizing the work of this body. He was a member of the Board of Architects which supervised the general design and arrangement for the Columbian Exhibition at Chicago in 1893.

The fact that Mr. Adler was always ready and willing to advise with any of the younger or even older members of the profession at all times on any matter that might be laid before him, endeared him to all who knew him, and showed the generosity of his nature. It was so well known among the profession that his decisions were based on equity and good judgment, that his opinions were frequently sought by members of the profession. In fact, his mind was so judicial in its character, that his former partner, Mr. Sullivan, in commenting upon his demise, said: "The bench lost an excellent judge when Mr. Adler became an architect." This qualification, combined with unswerving honesty, close attention to detail, and excellent judgment exercised throughout his career, resulted in his leaving many material achievements of excellent design as fitting monuments to his memory.

Mr. Adler was elected a member of the Society January 7, 1879. He died April 16, 1900, leaving a widow, a daughter and two sons.

# ABSTRACT OF THE MINUTES OF THE SOCIETY.

*REGULAR MEETING—September 3, 1902.*

A regular meeting (No. 477) of the Western Society of Engineers was held in the Society Rooms on the evening of September 3rd, with President Finley in the Chair and 101 members and guests (including ladies) present.

The Secretary announced that the Board of Direction, at its meeting held September 3rd, had elected the following list of applicants as members of the Western Society of Engineers:

Walter J. Parsons, Pittsburg, Pa., Active.
Frank J. Koza, Chicago, Junior.
Harry B. Boardman, Chicago, Associate.
Wm. D. Ball, Chicago, Active.
Frank D. Nash, Chicago, Active.
Roger B. Williams, Jr., Chicago, Junior.
A. S. Baldwin, Chicago, Active.
Wm. D. Jones, Chicago, Active.

The Secretary also announced that the following list of applicants had been referred to the Membership Committee for consideration:

Peter C. McArdle, Chicago, Active.
John A. Giles, Chicago, Active.
Arthur J. Mason, Chicago, Active.
Eugene Worthing, Chicago, Associate.
Walter J. Towne, Baraboo, Wis., Active.
H. E. French, Chicago, Active.
John T. Dickerson, Chicago, Junior.
Geo. W. Scott, Chicago, Active.

At the regular meeting of the Society held May 7th, the following motion was made by Mr. James A. Seddon: "That, on account of the importance of this question of the adoption of the metric system and the value that would follow from an endorsement of the measure now before Congress by the Western Society of Engineers, the Board of Direction be asked to consider the matter and to formulate a Resolution and Memorial to the Washington authorities, which Resolution and Memorial are to be presented at the next regular meeting of this Society for action."

At the regular meeting of the Society held June 4th, President Finley stated that the Board of Direction at its meeting held June 3rd had decided to call a special meeting of the Society for June 18th, for the purpose of discussing the subject of the metric system, after which the question of the position of the Society toward the bill would be submitted to the members by letter ballot. The consensus of opinion at the meeting of June 18th was decidedly in favor of the metric system.

In accordance with the above, a letter ballot was taken, with the result, (as reported to the Board of Direction on June 3rd,) of 153 votes received,—130 in favor and 23 against the system.

Mr. Modjeski moved that the Chair be requested to appoint a Committee to draw up proper resolutions to the effect that the Western Society of Engineers favors the adoption of the metric system by the Government, these resolutions to be presented at the next regular meeting of the Society. Motion carried.

In regard to the progress made by the Committee on the Installation of the Bench Standard in this City, the Secretary read the following letter from the Chairman of that Committee, Mr. John Ericson:

"I wish to state that since my last report I have been in communication with Lieut. Col, Ernst of the U. S. Engineer Corps, Mr. Henry I. Cobb, architect for the new Government building, and Mr. Stratton, Director of the National Bureau of Standards. Mr. Cobb expresses himself as being in entire sympathy with our effort and that he will do all he can to give us the required space in the Government building for a bench standard. All that I have been waiting for to call a meeting of the committee, for the purpose of taking final action, has been some plans for such a standard bench made under the direction of Mr. Stratton. On July 30 I received the following letter from E. B. Rosa, Acting Director of the National Bureau of Standards:

"'In reply to yours of the 28th inst. I have to state that our plans for standard bench are nearly completed and copies of them will be forwarded to you and to Mr. Cobb, as requested, within the next few days.'"

"I regret to state that so far I have not received any plans or had any further word from the National Bureau of Standards. I have again written to Mr. Stratton, asking him to kindly forward the plans as soon as possible. When these plans shall have been received I shall call the Committee together and I believe we then will be in a position to take final action, so that we can then report to the Society."

As there was no further business before the Society, the President then introduced Mr. Wm. J. Karner, who presented a paper written by Mr. E. L. Corthell on "Engineering in Argentina." The paper was illustrated by many lantern slides.

The meeting adjourned about 9:30, when light refreshments were served.

### *EXTRA MEETING—September 17, 1902.*

A meeting of the Society (No. 478) was called to order at 8:15 p. m. with President Finley in the Chair, and about 160 members and guests present.

Mr. Finley announced that the Society had received an invitation to visit Purdue University; that the Entertainment Committee were now making arrangements to take advantage of this invitation and will probably select some day in the early part of October.

This being an extra meeting, and there being no business to bring before the Society, Mr Finley then introduced Mr. Geo. W. Jackson, General Manager and Engineer of the Illinois Telephone & Telegraph Construction Company, who presented a paper on the "Scope, Extent and Construction of the Underground Conduits of the Illinois Telephone & Telegraph Company in Chicago." This paper was illustrated with lantern slides. At the conclusion of the paper there was a short discussion from Messrs. Moorehouse, Warder, Love, Hatch, Eidmann, L. E. Cooley and Liljencrantz.

The second paper for the evening on "The Automatic Switchboard and Telephone Combined," was presented by Mr. J. F. Crook. This paper was illustrated by working models under the direction of Mr. A. E. Keith.

The meeting adjourned about 10 P. M.

## THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what, for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc.

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

### Rules to Govern the Conduct of this Directory.

**First.** Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

**Second.** When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon, on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

**Third.** Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

**Fourth.** Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of application, and then taken off and destroyed. A brief abstract of each application, identified by number only, and stating character of position sought and salary expected, will be published in the JOURNAL. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

**Fifth.** Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is hoped that this arrangement of applications, etc., filed at the offices of the Society, will result in benefit to those members who are seeking a professional engagement.

BY ORDER OF THE BOARD OF DIRECTION.

J. H. WARDER, Secretary.

August 5, 1902.

# ABSTRACT OF APPLICATIONS FOR EMPLOYMENT.

No. 1—Sept. 14, 1902.

*Position Desired.*—Location or construction engineer or chief engineer for R. R. Co.

*Experience.*—For over 30 years engaged in engineering work—most of this time on R. R. surveys and construction. Have held position of assistant, division and chief engineer of prominent railroads in Illinois and adjacent States.

Nos. 2 and 3—Positions secured.

No 4—Oct. 6, 1902.

*Position Desired.*—Structural work in railroad, bridge, or consulting engineers' office. A combined field and office position desired.

*Experience.*—Graduate in civil engineering, University of Wisconsin. Has had practical work in a bridge shop, and worked as a draughtsman with a prominent bridge company, also in bridge department of a prominent railway. Have been lately engaged on and at present is resident engineer for a railway company engaged on "change of grade," "double tracking," "location" and "new construction."

No. 5—Oct. 6, 1902.

*Employment Desired*—In promoting, locating, canvassing for subscriptions and right of way for railroads, or engineering duties of location and construction of water reservoirs. Promoting new railways a specialty.

*Experience.*—Of a practical character of many years in locating, construction, etc. For over 20 years was chief engineer of an Illinois railroad—afterwards absorbed by another company.

No. 6—Oct. 14, 1902.

*Position Desired*—With a civil engineer or contracting firm engaged in engineering work where advance in professional knowledge and work would be possible.

*Experience.*—Graduate in C. E. University of Illinois. Have held position as transitman and assistant engineer with E. J. & E. R. R. Draughtsman with a large bridge company. Have had some experience in underground conduit work and am now in charge of erection of a bridge for a traction company.

# WESTERN SOCIETY OF ENGINEERS

Secretary's Office, Library, Reading Room and Meeting Room
1734-41 Monadnock Block, Chicago

## LIST OF OFFICERS FOR 1902

President........ ....................W. H. Finley
First Vice-President.................Ralph Modjeski
Second Vice-President......Prof. L. P. Breckenridge
Treasurer........... ...............Andrews Allen

## TRUSTEES

B. J. Arnold....................................Term expires January, 1903
C. W. Hotchkiss........................... .Term expires January, 1904
J. W. Alvord....................................Term expires January, 1905

**The above named officers of the Society constitute its Board of Direction**

Secretary and Librarian
J. H. WARDER

## COMMITTEES

*On Finance*—Ralph Modjeski, Andrews Allen, Daniel Royse.
*On Publication*—T. W. Snow, E. E. R. Tratman, Prof. L. P. Breckenridge.
*On Membership*—C. W. Hotchkiss, C. L. Strobel, Wm. M. Hughes.
*On Library*—J. W. Alvord, B. J. Arnold, Benj. Wolhaupter.
*On Entertainment*—W. J. Karner, C. W. Melcher, J. H. Spengler.

## MEETINGS

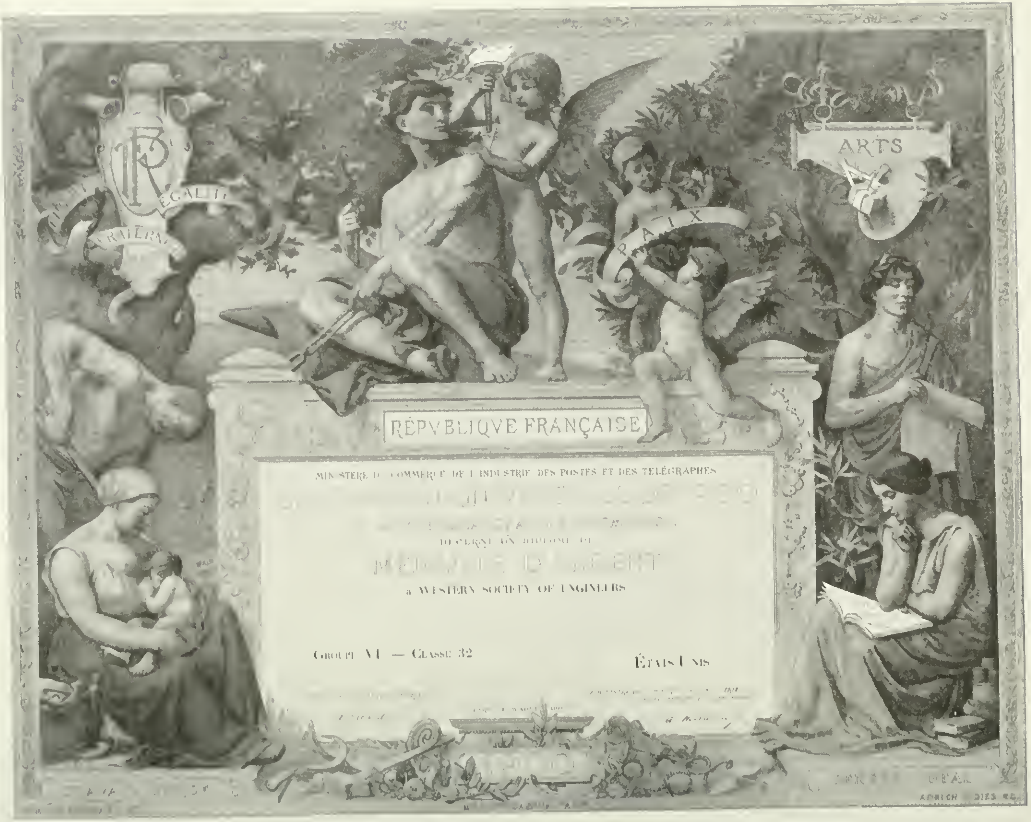
Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

Board of Direction—The Tuesday preceeding the 1st Wednesday of each month.

## NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the Journal.



ARTS
PAIX
ÉGALITÉ
FRATERNITÉ

RÉPVBLIQVE FRANÇAISE

MINISTÈRE DU COMMERCE DE L'INDUSTRIE DES POSTES ET DES TÉLÉGRAPHES

à WESTERN SOCIETY OF ENGINEERS

GROUPE VI — CLASSE 32

ÉTATS UNIS

Diploma awarded the Western Society of Engineers for their exhibit at the Paris Exposition, 1900.

Journal of the
Western Society of Engineers.

VOL. VII. DECEMBER, 1902. NO. 6.

## CLVII.

## MODERN HANDLING OF IRON ORE ON THE GREAT LAKES.

By Jas. N. Hatch, M. W. S. E.

*Presented October 1, 1902.*

In what shall be said regarding the great iron industry, I have decided to depart from that time honored and almost universal custom of beginning by quoting from the fifth chapter of Genesis, in which Tubal-cain is introduced as the first known worker of iron. I know this is a radical departure from a well-established custom, but when I state my reasons for this innovation, I trust I may be pardoned for this apparent sacrilege. The first reason is the fact that this talk is not intended as an historical account of the iron and steel industry, but rather a glimpse of some of the modern methods of mining and transporting the constituents of iron and steel, and need not therefore begin with the antediluvian times. The second reason is the fact that after long and careful research I was unable to find anything that would indicate that Tubal-cain belonged to the Amalgamated Association of Ironworkers, and I did not think it prudent at this time to give public commendation to the actions of a scab.

As the time that can be taken for this paper will not permit of more than a glimpse at a few of the modern appliances now in use, it will be necessary to confine ourselves to very recent times and to a comparatively small spot on the earth's surface. Had we time, I should greatly enjoy following with you the iron industry from its beginning in the United States. We could then see the vicissitudes through which it has been carried forward; how its growth during the colonial development of America was restricted by arbitrary legislation and stunted by ignorant prejudice. I regret that I can not give you some glimpses of the crude forges and rolling mills built within the forest primeval; relate something of the moonshine mills of revolutionary times, some of the ruins of which may still be found; or contrast the ore trains of pack-horses with the ore trains of to-day. I wish we might follow in detail the center of the iron industry as it has gradually moved westward from the Atlantic coast until now it is found in the vicinity of Youngstown, Ohio. Or dealing more directly with questions of transportation, it would be interesting to see how, in 1789, the crank for the first sawmill in Ohio was carried over the Allegheny mountains by pack-horses to the Youghiogheny river, and there shipped by water to Marietta. It weighed 180 pounds and was built at New Haven, Conn. And to contrast this with a crank shaft built in 1899 in Cleveland, Ohio, for a street railway in Scotland, in which the question of transportation to its destination was so insignificant as to call forth no comment, although this shaft weighed 140,000 pounds.

But time will not permit of even a glimpse at these interesting scenes, and it has therefore seemed necessary to confine this paper to the mining and transportation methods during the last fifty years and to that geographical territory lying between the Lake Superior iron mines and the Pittsburg iron district. As modern civilization would be impossible without an abundance of cheap iron and steel, it cannot but be interesting to examine into some of the methods that have brought about this condition, remembering that every factor that has entered into the lowering of the cost of steel has been a potent factor in the advancement of civilization and the betterment of modern social life.

So with the aid of a few illustrations, I invite you to a little journey of inspection among the iron ore mines, along the docks, and down through the Great Lakes to the steel making plants. In the course of the journey there will be found the embodiment of some of the very latest ideas in modern methods of mining, handling and shipping of ore, the like of which can be found nowhere else in the world. I repeat modern methods, in a superlative degree, and if what is seen to-night in this little tour does not conform with what may be found in a week or a month from now, remember that I am not telling of future but of past methods. The improvement in machinery is so rapid that often before a new style of machine is installed and in operation it is found to be antiquated, it has been outgrown.

We hear so much in these days of how America is able to undersell the whole world in steel products, and we are informed that the most important factor that has operated to bring this about is the excellent and cunningly devised machinery used by American manufacturers. But have we considered what this machinery is? Are we not apt to think of this machinery as comprised in the great machines seen around the rolling mills and steel plants? These machines are important, in fact indispensable, but there are other machines that are no less important about which we hear comparatively little. It would make little difference how excellent was the steel making machinery, if the ore could not be had for less than $10.00 or $12.00 per ton steel could not be produced on a very cheap basis. The machinery that has done as much as, if not more than, any other to bring steel down to its present low price, is the labor-saving machinery used for handling the raw materials. So significant is this item that now ore can be mined in the Superior region, shipped a hundred miles by rail, transferred from train to ship, sent 600 to 800 miles by water, again transferred to trains and hauled 150 miles inland to Pittsburg, and there unloaded and piled in stock piles, to be sold out on a profitable basis at $3.00 per ton. While this portion of the process does not guarantee cheap steel, the lack of such appliances would absolutely prohibit it.

Early in the history of the iron industry—for remember that steel has been produced on a commercial basis in the United States for only about 35 years—the mills and mines were located as near together as possible. Charcoal was the chief fuel, and water power the principal prime mover. And to us of the younger generation it is hard to realize that until 1854 this country made more pig iron with charcoal than with any other fuel; the next year charcoal was surpassed by anthracite coal, but it was not until 1869 that it was exceeded by bituminous coal. It was not difficult in early times to find the necessary elements in close proximity; the forests were abundant, and unlimited power was running to waste in every stream. So the early mills were established on the frontier, little towns grew up around these mills, which were metropolitan in their district. Scores of ruins of these charcoal furnaces and Catalan forges may be found in the middle west today. And many of the towns stand just as they did fifty years ago, far from any railroad, with the addition that now even the boats have ceased to make regular trips. So long as the mines and furnaces were in close proximity, the question of transportation was one of minor importance, but with discovery of the vast extent and richness of the ore beds of the Superior region, about forty years ago, and the simultaneous discovery of the value of the coal fields of Pennsylvania, in the making of both pig iron and steel, the problem of transportation rapidly became a most important one. The center of the iron industry had been moving gradually westward from the Atlantic coast as the demand in the west increased, and as the richer western ores were discovered, but when it was found that Connellsville coke was far superior to any other in the manufacture of steel, the attraction of this excellent fuel on the one hand, and of the rich lake ores on the other, soon made it manifest that the center of the steel industry must come to rest somewhere on a line drawn between these two points of attraction. As it takes approximately a ton of coke to a ton of ore, it would seem to make little difference at what point between these two extremes the mills were located. But as Pittsburg from other causes had already become an iron center there was no good reason why it should not remain so. It will thus be seen that with the location of the mines fixed on the one hand and the furnaces on the other, the problem of transportation between these two objective points became one of utmost importance. American ingenuity was not slow to discern the promising field for the exercise of inventive genius, and those who have been able to cope with these problems have not gone unrewarded.

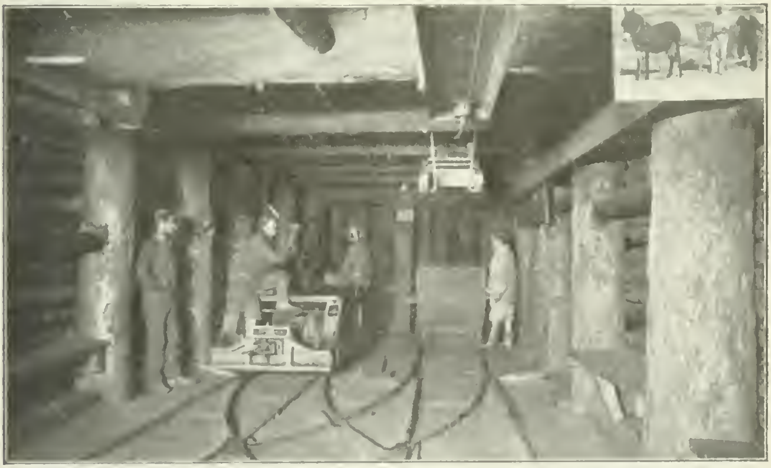
The first lake shipment of ore from the Superior region was made in 1856. Prior to that, it is estimated that there had been taken from these mines a total of about 75,000 tons. Before 1856 the ore was worked up in the furnaces near the mines. In 1856 the output from the Superior region, which was then confined to the Marquette range, was 6,790 tons. This ore was mined by sinking shafts through the top soil till the vein of ore was reached, or by running drifts into the sides of the hills. The ore was loosened up with pick and shovel, thrown into buckets, and hoisted to the surface by means of windlasses turned by hand or by use of horse whims. On the inclined drifts carts and wheelbarrows were made use of as being more efficient. At the mouth of the mines the ore was loaded into wagons, and hauled to the lake shore with teams of mules and there piled up ready for shipment. In 1855 a plank road was built from Marquette to the mines to better facilitate the carrying of the ore that was to be shipped down the lakes.

These methods of mining and transporting ore were of necessity very expensive, and the ore had cost more by the time it was aboard the vessel, ready to start on its journey, than the same ore would cost today delivered at the furnace 1,000 miles distant.

In 1857 the first railroad for carrying ore was completed from Marquette to the adjacent mines, and in that year the annual output was four times what it had been the year previous, and three times the aggregate that had been sent out prior to 1857. The locks at Sault Ste. Marie had been completed in the summer of 1855. Power drills driven by steam or compressed air were introduced in 1878 and tram cars in 1880. Since then, the discovery of new mines, the invention of new methods of mining and the improved hauling and hoisting machinery used at the mines have so far reduced the cost that ore which would have sold for several dollars per ton fifty years ago has of late been sold at the mines piled up ready for shipment as low as 70 cents per ton. Machinery is employed for almost every move the ore makes from the time it is dislodged from its native bank till it is piled up as finished steel.

About 70 per cent of the ore is still taken from deep mines, where a shaft is sunk, often to a depth of 1,000 to 1,500 feet. But even with these deep mines, ore can be obtained very cheaply, since close competition has forced the operator to be constantly on the watch, ready to seize every possible improvement that would tend to reduce the cost of production. The use of electric, pneumatic and hydraulic machinery and of cable and electric tramways and hoists, has so far improved conditions that now one man will do the work that required a score of men to accomplish twenty-five years ago.

To enter the mine cage and be lowered into the bowels of the earth a thousand or more feet may not seem to the uninitiated a most reassuring trip, but the real danger from such a venture is very slight, probably not half so great as to spend the same time on the sidewalks of Chicago, and certainly not more hazardous than riding in the elevators of our business buildings.



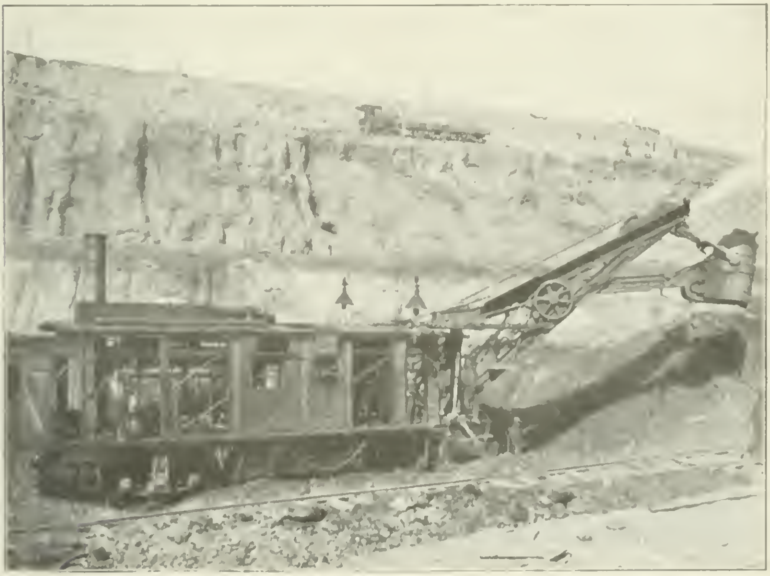
The illustration shows a portion of the Lake Angeline mine, near Marquette, Michigan, from which a very good idea may be formed of an interior of an iron mine. As shown here, an iron mine of soft ore is a veritable forest of heavy timbers. The shaft from the surface comes down just back of where the miners stand. The electric locomotive which is shown is one of the regular motors used for hauling the ore trains up from the distant workings, and have replaced the proverbial mine mule. This mine is directly under Lake Angeline, or what was Lake Angeline before the water was pumped out. There is no lake there now.

Another illustration shows a power drill working in the rock, and it will be noticed that no props are required at this point. When a number of holes are drilled, blasts are put in and set off simultaneously by electric sparks, throwing down great masses of material. Loaded cars are seen standing on the siding a little further down the track. In this view the working space is ample, and it would not lead one to suppose that mining was so unpleasant after all, but as we go further back a marked diminution in space is observed.

No attempt will be made to go into the various systems employed in mining, but suffice it to say that owing to the different conditions met with it is necessary to resort to a number of distinct methods, each adapted to its own locality.

Before leaving the district of deep mines it may be interesting to notice the effect which this work has on the general contour of the country. A crater is shown in the next illustration, where the ore has been drawn from beneath and the undermined ore allowed to cave in. It will be seen that the top earth has been previously stripped off, so it would not become mixed with the ore. That these changes in the topography of the country are of no insignificant proportions may be understood when it is realized that the present annual output of ore from the Superior region is equivalent to 50 acres dug to a depth of one hundred feet.

As was said, 70 per cent of the iron ore of the United States is still taken from deep mines; the other 30 per cent is mined from open workings, where it is dislodged and loaded mostly by means of the steam shovel. The top earth, trees, gravel, loam, etc., are first stripped off, leaving the ore exposed in the form of immense banks of loose red earth that can be easily shoveled. The steam



shovel is then put to work against this bank, digging the ore and loading it into cars. A train of ore cars is shifted on a track beside the shovel into which the ore is emptied. Several shovels can be worked on one bank by working in terraces, as shown. The great depths of these banks of rich ore can be realized from the picture. The method of operating a steam shovel is doubtless familiar to most of us. The boom can be swung around through nearly an entire circle, carrying the bucket to wherever it is needed. A chain over the boom sheave draws the bucket up, loading it as it rises. The chain beneath the boom is operated by hand and pulls open a latch, which lets the bottom fall out of the bucket, dumping the load. The load that a bucket takes up at each scoop is about 5½ tons. Three or four men are all that are required to keep a steam shovel in operation, with which 5,000 to 6,000 tons can be loaded per day, or about 150 to 200 car loads. The cars shown are hopper-bottom wooden cars, carrying 30 to 35 tons each. The bottom of the cars can be opened to allow the ore to drop out below. To load 6,000 tons of ore with hand shovels in ten hours would require a force of from 75 to 100 men. As the cars are loaded, they are pulled out of the ore pit by a shifting locomotive and made up into trains of 40 or 50 cars each, and started off for the docks.

With this little expedition among the mines it is hoped that a fair general idea has been obtained of the modern methods of mining and loading ore, and we will now leave the mines and follow it as it starts on its journey out into the world. The distance from the mines to the docks varies from a few miles to something over a hundred miles. The locomotives used on these roads are among the most powerful in use anywhere, and, taken in connection with the other equipment of the road, make a unit that is not the least among the various facilities for cheapening the cost of iron, and are not surpassed in efficiency by any railroad facilities in the world.

In an article written by Horace Greeley in 1869, he says: "Only last winter I saw a long string of teams drawing on sleds iron ore from the beds at Amenia to the furnaces in Connecticut, six or eight miles away. In England a railroad would be doing the same work at less than half the cost, at least ten years ago. As time goes on we will shorten and cheapen these routes. Every year of successful production wears smoother the ways over which raw materials glide to meet each other. Our railroad system, though extensive and rapidly increasing, is far less perfect as a handmaid to manufacture than the British, which connects almost every ore bed with almost every coal mine in the island."

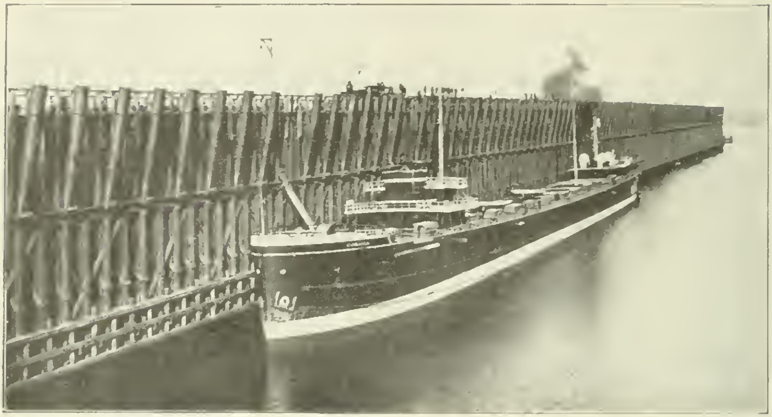
That Horace Greeley's prophecy has been realized in a more rapid manner than his most sanguine anticipation ever pictured, is certain. His injunction was that we follow the lead of the older countries, little dreaming that in thirty short years all the older countries would be sending delegations here to discover the secrets of American methods.

In 1901, an Englishman writing of American steel-making methods, said: "Only a few of the British manufacturers in the iron industry have at all realized the forces that are at work; the enormous natural advantages and resources which the Americans possess, with their cheap ore and coal, combined with their skill and enterprise, their labor-saving appliances, their low railroad rates and water freightage on their ores from mines to furnace, and the best equipped works in the world. All these place them at a great advantage, whilst England has hitherto been working according to antiquated methods. The consequence is, that unless she at once wakes up and adapts herself to the requirements, her past prestige will pass away. Those manufacturers who have visited the States are quite alive to the seriousness of the situation, and they appreciate the necessity of inventing new methods, or of adopting those in operation in America."

The journey from the mines to the ore docks is generally an uneventful one, so we may hurry over this and stop off at the switch yards, near the docks. These yards have a storage capacity for hundreds of cars. The trains are drawn into the yards by mammoth engines, but are shifted out upon the docks by lighter ones. These docks at the different harbors are being constantly improved and enlarged at a tremendous expense. Some of them are nearly 2,000 feet in length and can accommodate three vessels, end on. There were in the Superior region in 1900 an aggregate of 4,354 storage pockets, with a storage capacity of 660,000 tons, and a length of over five miles. The cost of construction is estimated at over $7,000,000.

A dock at North Escanaba is one of the largest and best equipped on the lakes. It is 1,920 feet long and 70 feet high, with 320 pockets, the capacity of each being 160 tons, making the aggregate capacity 51,000 tons.

At first thought it would seem that the interest on the capital invested in these works would cut down the annual saving a very considerable amount, but when it is remembered that one of these docks can accommodate as many vessels as a dozen old-fashioned docks could, it will be seen that these are less expensive docks per ton of ore moved than the old ones were, to say nothing of the saving in the handling of the ore. Another great saving that is effected is the fewer cars required, as the cars can now be kept on the road most of the time instead of lying in the yards waiting to be unloaded.



The picture shows quite clearly how a vessel is loaded at the docks. From each pocket there is a chute correspondingly numbered, which is let down into the hatch of the vessel. A gate is opened at the top of the chute, which allows the contents of the pocket to discharge into the vessel.

In the "fifties," when the first shipments of ore began from the Superior region, a vessel of 800 or 1,000 tons was considered a large freighter. To load one of these 800-ton vessels was no small task. The ore was dumped from wagons upon piles along the wharf. When a vessel came in to load, an army of men were put to work shoveling the ore into wheelbarrows, wheeling it along "runs" out upon the vessel and dumping it into the hold. It required a gang of twenty men, working ten hours per day, eight to ten days to load 800 tons of ore, at a cost of 40 cents per ton.

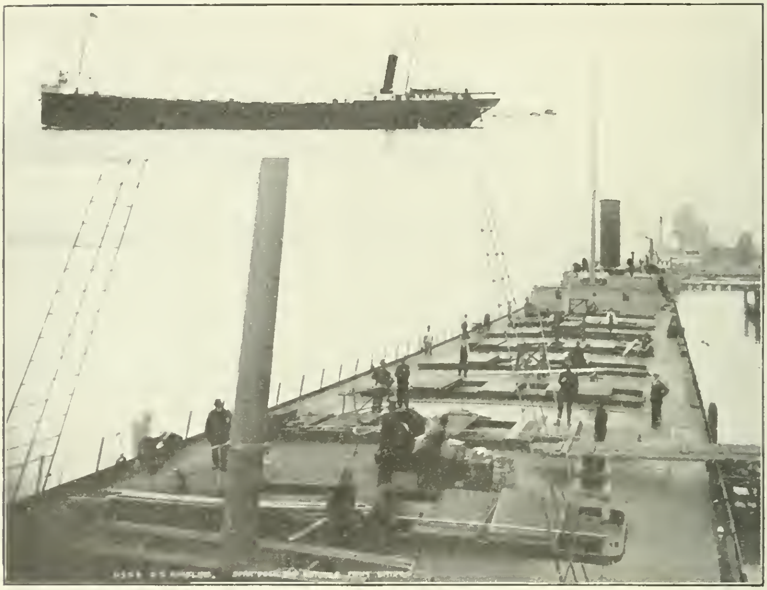
Now a vessel of ten times that capacity will load in three or four hours, at a cost of but a few dollars for the entire cargo. It is no uncommon thing for a modern vessel to load and clear in an hour and a half. The dock at Duluth for the Duluth, Missabi & Northern Railway Co. was built at a cost of $425,000. In June, 1901, this dock made a record that had never been approached on the lakes before. There was moved in 24 hours, 64,000 tons of ore, an equivalent of a season's shipment of 13,000,000 tons. This ore was taken into 14 large boats, the average cargo of which was 4,571 gross tons.

With this glimpse of the loading methods on the upper lakes, we will pass on to an examination of the lake carrying facilities. I regret that the time will not permit of an examination of the upper lake coal docks, which are a study of themselves. As has been intimated, the improvement in ore carrying vessels on the great lakes has not been neglected, among the various other factors that have been devised to cheapen the price of steel. So great and so rapid has this improvement been, that in the last ten years freight rates have been cut almost in half.

| Years. | Shipment. | Rates. |  | Years. | Shipment | Rates. |  |
|---|---|---|---|---|---|---|---|
|  |  | Marquette. | Escanaba. |  |  | Marquette. | Escanaba. |
| 1854 | 3,000 | . ....... | .. ........ | 1872 | 948,533 | $2.85–$6.60 | $2.00–$5.25 |
| 1855 | 4,149 | ............ | ....... . . | 1873 | 1,195,234 | 3.25– 4 00 | 2 30– 3.00 |
| 1856 | 6,790 | $3.00–..... | . ........ | 1874 | 899,934 | 1.60– 2 50 | 1.30– 1.40 |
| 1857 | 25,646 | 3.00– | ... ....... | 1875 | 881,166 | 1.30– 2.50 | 1.10– 1.30 |
| 1858 | 22,876 | 2.00–$2 50 | ........ | 1876 | 933,311 | 1.25– 2.20 | .70– 1.40 |
| 1859 | 68,832 | 2.00– 2.50 | .......... | 1877 | 1,025,129 | 1.25– 2.00 | .65– 1.50 |
| 1860 | 114,410 | 2.00– 2.50 | .......... | 1878 | 1,127,583 | 1.00– 1.50 | .60– 1.15 |
| 1861 | 19,909 | 2.00– 3 00 | .. ...... | 1879 | 1,420,745 | 1 25– 3.00 | .70– 2.10 |
| 1862 | 124,169 | 2.25– 4.50 | ........... | 1880 | 1,948,334 | 2.00– 2.75 | 1.50– 2 00 |
| 1863 | 203,055 | 3.00– 4.00 | ....... . | 1881 | 2,125,729 | 2.00– 2.30 | 1.00– 1.60 |
| 1864 | 247,059 | 3.00 5.00 | ......... | 1882 | 2,656,933 | 1.25– 2.00 | .90– 1.40 |
| 1865 | 193,758 | 2 05– 5.00 | .. .. .. ... | 1883 | 2,518,048 | 1.30– 1.75 | .90– 1.50 |
| 1866 | 296,713 | 2.75– 6.50 | $2.50–$5.75 | 1884 | 2,225,146 | .. . 1.00 | ..... .65 |
| 1867 | 565,504 | 2.00– 4.00 | 1.05– 3.05 | 1885 | 2,205,190 | ...... 1.40 | . .. . 1.00 |
| 1868 | 510,522 | 2.25– 3.25 | 1.06– 2.06 | 1886 | 3,179,511 | ...... 1.75 | ... .. 1.35 |
| 1869 | 639,097 | 2.75– 4.50 | 1.05– 2 05 | 1887 | 3,934,339 | .... . 2.15 | ...... 1.75 |
| 1870 | 859,507 | 2.05– 3.25 | 1.65– 2.50 | 1888 | 4,113,803 | 1.10– 1.15 | .90– 1.40 |
| 1871 | 813,084 | 2.05– 4.00 | 1.50– 2.50 | 1889 | 5,856,169 | .90– 1 25 | .90– 1.25 |
| ..... | . ..... | ...... ... | ........... | 1890 | 7,141,656 | 1.25– 1.10 | 1.10– 1.00 |

This table shows the rate since 1856. It will be seen that $3.00 was the prevailing rate in 1856-57, and how this rate has been gradually reduced with certain fluctuations, until 1898, when it was pretty firmly established at 60 cents per ton. The wave of prosperity has carried this rate up again during the last two years, but there is no economic reason for this increase. These rates are simply the toll charges from the upper lake ports to the lower lake ports, and do not include dock charges, loading or unloading. It will be noticed that the rates of 1898 were only one-fifth of the rates of 1856, but it is claimed that owing to increased draught, larger vessels, more economical engines, prompt loading and discharging, etc, the transportation companies earn as much, on the long hauls, at these lower rates as they earned formerly at the higher rates.

In the past five years the size of lake vessels has increased tremendously. Steel vessels of 500 feet in length and 8,000 tons burden, and of 12,000 tons displacement, are now being used, although twelve or fifteen years ago it was not believed any such vessels would ever be used on the great lakes. When the "Poe" lock the largest canal lock in the world, 600 feet long by 100 feet wide was designed for Sault Ste. Marie, it was supposed that the lock would accommodate four of the largest vessels that would ever be in use on the great lakes, two abreast; but it was scarcely finished before it had been outgrown.



An illustration shows a view looking aft from the bridge on the ore carrier "Angeline." It is interesting to note the arrangement of the steel deck and the number and size of the openings. A

large vessel has fifteen or more of the hatches, which will be referred to later. These great vessels are especially designed for the service in which they are to be employed. There are several hundred of these vessels in operation in the ore trade, capable of moving in the season of open navigation, 25,000,000 tons of ore. Each year sees more and larger vessels added to the already large fleet. The newer ones are made entirely of steel, and have been built at the various shipyards along the lakes.

Two steel ore carriers are shown in the locks at the "Soo." These are vessels of moderate size, probably of 3,000 or 4,000 tons burden and not over 300 feet long. The locks will accommodate four vessels of this size. During the shipping season of seven or eight months a vessel can make about twenty round trips. Many of the newer vessels are designed for towing barges; with this arrangement, a vessel of the most modern type can tow two large steel barges at a speed of eleven miles per hour, moving an aggregate cargo of 20,000 tons. This constitutes a saving both in power, capital invested, and wages to seamen.

It might be interesting to note here that all these reductions in cost have been accomplished without reducing actual wages. In fact, wages for this kind of work have increased. It is said that seamen on the ore vessels are among the best paid men on the lakes. The captains receive $1,800 and the mates $1.500 per annum and expenses, and the other officers and the sailors in proportion. The fuel bills for vessels such as we have seen will amount to $500 to $1,000 per trip, according to the size of the vessel. With the extremely rapid coal handling machinery now in vogue at the various lake docks, many of the vessels are enabled to return up the lakes with a cargo of coal, without the necessity of much delay. This is equivalent to another reduction in the freight rates on ore.

| Year. | Tons | Year. | Tons. | Year. | Tons. |
|---|---|---|---|---|---|
| Previous to 1854 | 75,082 | 1869 | 639,097 | 1885 | 2,487,446 |
| 1854 | 3,000 | 1870 | 859,507 | 1886 | 3,637,753 |
| 1855 | 1,149 | 1871 | 813,981 | 1887 | 4,729,352 |
| 1856 | 6,790 | 1872 | 948,533 | 1888 | 5,007,596 |
| 1857 | 25,646 | 1873 | 1,195,234 | 1889 | 7,588,076 |
| 1858 | 22,876 | 1874 | 899,834 | 1890 | 8,982,531 |
| 1859 | 68,632 | 1875 | 881,166 | 1891 | 7,661,587 |
| 1860 | 114,110 | 1876 | 993,311 | 1892 | 9.071,082 |
| 1861 | 49,909 | 1877 | 1,025,129 | 1893 | 6,058,955 |
| 1862 | 124,169 | 1878 | 1,127,583 | 1894 | 7,748,223 |
| 1863 | 203,655 | 1879 | 1,420,745 | 1895 | 10,429,937 |
| 1864 | 247 059 | 1880 | 1,962,177 | 1896 | 9,934,828 |
| 1865 | 193,758 | 1881 | 2,323,640 | 1897 | 12,457,002 |
| 1866 | 296,713 | 1882 | 2 932,953 | 1898 | 14,300,000 |
| 1867 | 565,501 | 1883 | 2,580,223 | 1899 | 17,901,358 |
| 1868 | 510,522 | 1884 | 2,321,880 | 1900 | 18,570,315 |
| | | | | 1901 | 20,387,522 |

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* Shipments for 1902, reported December 13, is 27,450,000 tons.

This table shows the shipments of ore from the Superior region as far back as our records go. The year 1901 far outstripped all its predecessors, and the present year bids fair to again break all records. It will be interesting to note in this table the effect that different political crises have had on the movement of ore. In 1861, at the breaking out of the civil war, the ore receipts were less than half what they had been the previous year, and about one-third what they were the following. The panics of 1874-5 and of 1893-4 are plainly shown by the diminution in shipments.

About one-tenth of the ore sent down the lakes goes down Lake Michigan to Chicago; the remainder, in most part, goes into Lake Erie and is distributed among a number of receiving ports.

IRON ORE RECEIPTS AT LAKE ERIE PORTS—GROSS TONS.

| Ports. | 1901 | 1900 | 1899 | 1898 | 1897 | 1896 |
|---|---|---|---|---|---|---|
| Toledo | 798,298 | 645,147 | 792,348 | 414,012 | 416,438 | 301,794 |
| Sandusky | 33,017 | 154,542 | 87,499 | 136,200 | 79,792 | 58,667 |
| Huron | 431,311 | 321,914 | 263,600 | 126,755 | 198,231 | 226,515 |
| Lorain | 721,662 | 1,090,235 | 1,112,946 | 536,086 | 355,188 | 191,445 |
| Cleveland | 3,831,060 | 3,376,644 | 3,222,582 | 2,645,318 | 2,456,704 | 2,313,170 |
| Fairport | 1,181,776 | 1,085,554 | 1,241,013 | 912,879 | 1,008,340 | 941,446 |
| Ashtabula | 3,981,170 | 3,709,486 | 3,341,526 | 2,684,563 | 3,001,914 | 2,272,822 |
| Conneaut | 3,181,019 | 2,566,631 | 2,320,696 | 1,404,169 | 495,327 | 327,623 |
| Erie | 1,379,377 | 1,240,715 | 1,309,961 | 1,092,364 | 1,311,526 | 847,849 |
| Buffalo<br>Tonawanda | 1,475,386 | 1,616,919 | 1,530,016 | 1,075,975 | 797,446 | 545,101 |
| Total | 17,014,076 | 15,797,787 | 15,222,187 | 11,028,321 | 10,120,906 | 8,026,432 |

This table shows the principal receiving ports on Lake Erie, with the amount received at each during the past seven years. It will be seen that Ashtabula is in the lead, with Cleveland a close second, but with Conneaut gaining on them with rapid strides. It is also shown that the annual ore receipts have doubled within the last six years. As the shipping season depends on the period of open navigation, which is only about half the year, it is imperative that the ore should be handled as rapidly as possible until it is landed on the receiving docks. After that it can be distributed to the mills at any time during the winter. Statistics show that on December 1st of each year, from one-third to one-half of all the ore received during the shipping season is still stored at the receiving docks.

Rapid methods of loading ore and very good shipping appliances had been in vogue for some years before any good method for unloading ore from the vessels had been devised. And it may be said that even now unloading machinery is still in its infancy. I would venture the opinion that the next decade will see most of the present unloading machinery relegated to the scrap heap, and new machinery that shall be more efficient introduced. However, there has been for several years machinery in use that is such an improvement over the old methods that it has really marked a new era in the ore handling industry.

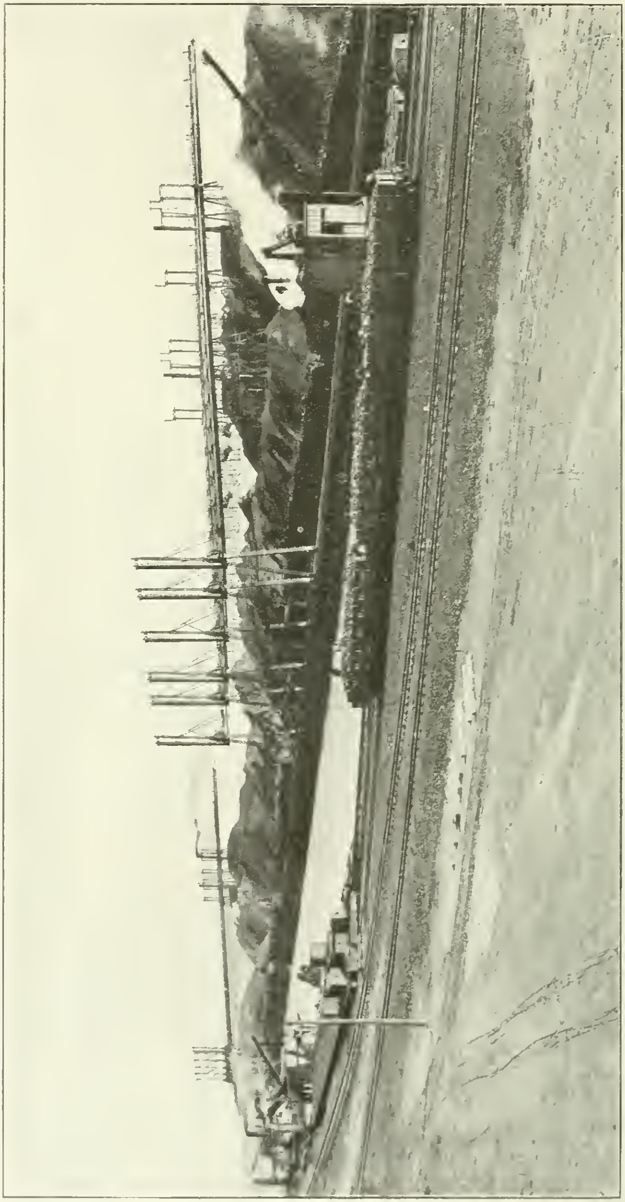
Before examining any of the unloading machinery in detail, it may be interesting to glance in a general way at several of the principal lower lake docks. A birdseye view of the docks of the Erie and Pennsylvania railroads at Cleveland would show about 100 unloading machines, with a daily unloading capacity of over 50,000 tons. The unloading machines here are largely composed of bridge tramways, and were made by the Brown Hoisting Machinery Co. of Cleveland. The immense stock piles may be seen here, and the capacity of the docks for storing ore can be realized.

Another very interesting example of unloading equipment can be seen in the harbor and dock equipment at Conneaut, Ohio. This is one of the very newest and best equipped harbors in the world, and one in which there is a good assortment of different makes of machines. These docks will accommodate nine ships at a time, and are equipped for unloading 25,000 tons of ore in ten hours. A vessel of 6,000 tons can clear in fourteen hours from arrival. In spite of this, it is said that during June and July of last year vessels lay in here two or three deep most of the time, waiting for an opportunity to discharge their cargoes.

Among the pioneer machines that proved successful as unloaders of ore and coal, the bridge tramway as constructed by the Brown Hoisting Machinery Co. is entitled to first place. In fact, Mr. Alexander Brown has been justly called the pioneer in this class of dock equipment. There are now a number of different makes of these machines, but the principle on which they work is much the same. Probably 75 per cent of all mechanical unloading at the present time on the great lakes is done with "Brownhoist" machinery.

The illustration shows one of the standard bridges tramway plants at Ashtabula, Ohio. These machines are generally run three in a set, with one engine house for the three, and one operator's house, but three operators and three engines. In this particular case two of the machines are fastened rigidly together with the engine house between them, but in the other cases the engine house is located entirely upon one machine. The single machines are operated from the engine by wire ropes running over sheaves, and can be as much as 100 feet away. That is, one machine can be 100 feet up the dock, the engine house between, and another 100 feet down the dock.

Three distinct motions are provided for in the hoisting engine; one for traversing the entire plant up and down the dock, which is transmitted by gearing, one for hoisting and lowering the bucket,

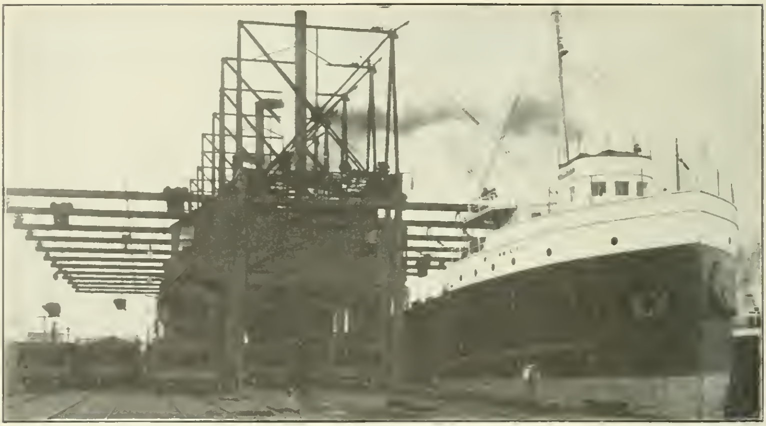


A Brown Hoist Standard Bridge Tramway Plant, Ashtabula, Ohio.

and the third for moving the trolley back and forth across the bridge. There is a track along the water edge on which the front end runs, and a double rail track under the back piers. These machines are provided with hinged aprons to be lifted up, when necessary to permit the vesssl to pass close to the wharf.

Along the chord of these bridges is a track on which a trolley is drawn back and forth, by means of a wire rope. Over the sheaves or pulleys on the trolley the hoist rope passes which carries the bucket. The bucket may be raised or lowered at any point along the bridge. When a vessel comes in to unload, the projecting aprons, which have all been in a vertical position, are let down over the boat. The bridges are shifted so as to bring one over each hatch of the vessel, or the front end of the bridges may be moved without moving the back end, bringing two aprons over one hatch, but allowing the back end to stand at quite a distance apart. This moving may be done either from the engine or with hand gear. The trucks are then clamped down to the track, and everything is ready for unloading. When the bucket is full it is raised up to the trolley where it is latched. The trolley is then drawn to any desired position and the buckets emptied. The buckets are what are known as self-righting tubs. These tubs are filled by men with shovels. There are small rollers on the bottom of the buckets which permit of their being moved about in the vessel as necessity requires. A number of buckets may be filling at the same time, and are lifted out as soon as filled. Dumping irons are clamped on the lower chord of the bridge, which will automatically trip the bucket and dump the load at any desired point along the bridge. The bucket then rights itself and is ready for the return trip. The length of trolley travel in a bridge tramway is not usually over 200 feet, although the Brown Company now have one in operation which is 550 feet long, including two cantilevers. As was said, the bridge tramway was one of the first successful unloading machines, and it was a marvel for speed compared with anything previously used. Under favorable conditions a bucket can make a round trip per minute, so that each bridge will unload 50 or 60 tons per hour. It is a very common thing for a vessel of from 2,500 to 4,000 or 5,000 tons to be unloaded in eight or ten hours. To keep a plant of six bridges in operation requires the services of nine men, viz., six operators, two firemen, and one general utility man.

The cost of unloading may be roughly stated at 1½ cents per ton, although records considerably less have been made. This does not include the cost of filling the buckets by hand shoveling in the vessels. This shoveling into buckets costs 10 to 12 cents per ton, which would bring the total cost of unloading up to perhaps 12½ to 15 cents per ton. The direct unloader is in principle much like



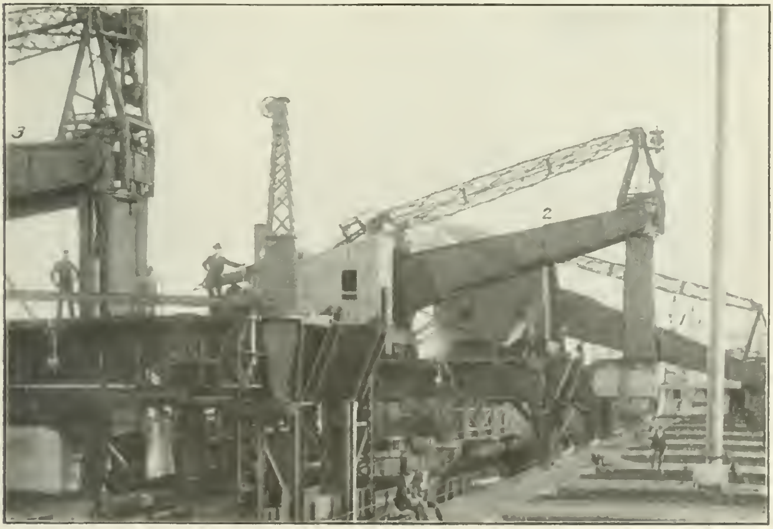
the bridge tramway, but works more rapidly. It is designed for unloading direct from the vessel to the cars, and does not provide for storing the ore in stock piles. There is a plant of twelve of McMyler's direct unloaders on the Conneaut docks. The buckets and trolleys are very similar to those just described, and are operated in a similar manner, but all the actions are much more rapid. The buckets can be hoisted at the rate of 400 feet per minute, and the trolley traversed along the track at 1,000 feet per minute. The whole machine can be shifted along the docks at comparatively a rapid rate. The length of trolley travel in the direct unloader seldom exceeds 100 feet. The Brown Company make a similar plant, and they sometimes introduce a little variation by putting the chord on a slope so that the empty bucket returns to the ship by gravity.

The King Bridge Co. have a number of machines at Conneaut. These machines have a number of distinctive features, one of which is, that the bucket may be raised or lowered at any point while the trolley is in motion, which offers some advantages. Another feature is that the runway forms the lower chord, so that no cross beams are required. Also the trusses are entirely above the chord, which is different from the "Brownhoist" system.

With all the above described machines, a large portion of the ore must be shoveled by hand into buckets, which is necessarily an expensive operation. The very newest unloading machinery is designed to obviate this hand work as far as possible, and the success already gained in this direction is not at all discouraging. One of the latest inventions in this line is known as the Hulet unloader, and is a radical departure from anything else devised for this class of work. Four of these machines, the first ever built, were put in operation on the Conneaut docks in the summer of 1899, and have been in successful operation since that time. They are built by Webster, Camp & Lane, of Akron, Ohio, and are certainly marvels of ingenuity. If they accomplish what the inventor expects of them, it would be no surprise if their introduction marked the era of a complete change in unloading machinery, whether or not these actual machines are the solution of the problem.

The whole machine is carried on two piers, which are supported at the bottom by trucks, resting on a track. This enables the entire machine to be shifted along the dock to any desired position. The power is all derived from the engine house, built within the back pier. Two plate girders carry the structure between these piers. On the top of these girders is a track running transversely to the other tracks, on which a carriage runs back and forth along the girder. All of the upper portion of the machine is supported on this carriage, and can be moved back and forth between the piers. On the front end of this carriage is a vertical support, to which is attached the walking beam. At the rear of the walking beam is located the hydraulic cylinders which operate it. At the front end of the walking beam there is a mast, to the bottom of which is attached the grab bucket. This mast is pivoted at the top, and may be turned through an entire circle. The motions of the machine are controlled by an operator who is located inside the mast.

When a vessel is tied up ready for unloading, the unloader is shifted on the wharf until the mast is vertically over one of the



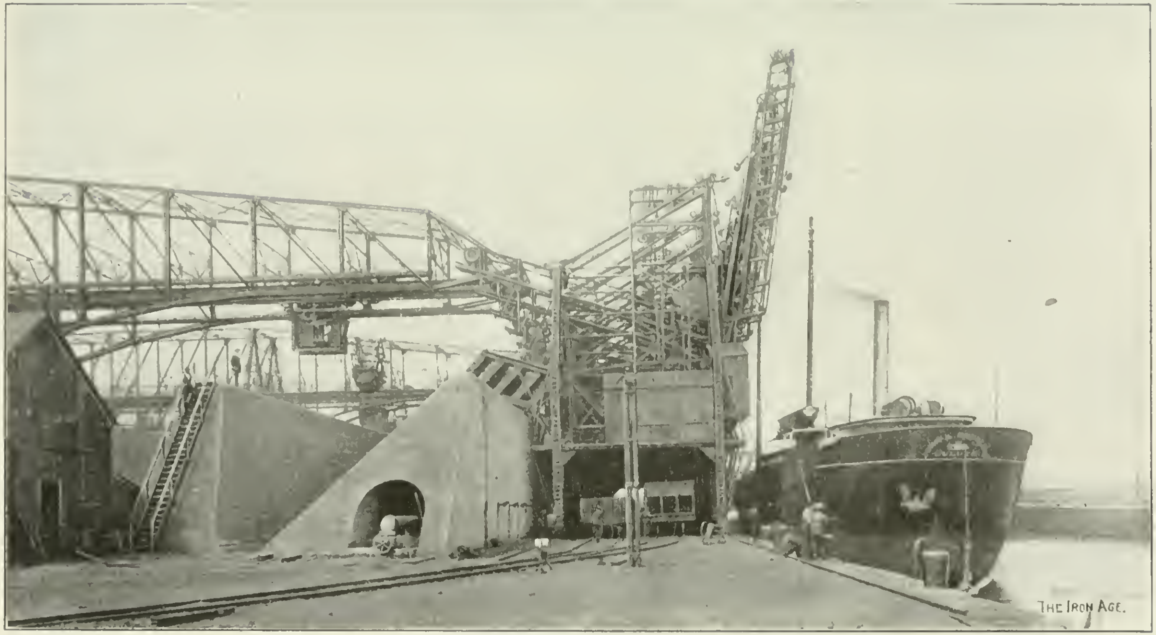
open hatches of the vessel. The walking beam is then lowered, with the bucket open, until the bucket rests on the ore pile in the hold of the vessel. The bucket is held hard down on the ore and closed, so as to dig into the ore and fill itself in closing. These buckets pick up ten tons at a grab. There are shown three machines working on a vessel; No. 1 has the bucket in the hold loading, and No. 3 shows the bucket open after having dropped the ore into the cars which stand under the bridge.

When it is desired to store ore in the stock piles, a tramway is run back from the end of the unloader bridge, which receives the ore and carries it back any desired distance. It is claimed that these machines will remove from 90 per cent to 95 per cent of the ore from the vessel without any shoveling whatever. As shown, the bucket is set eccentric on the mast, so that in turning the mast through a circle the bucket has a sweep of about nine feet radius, which enables it to reach to the bilge of any of the modern vessels. One of these will unload about 200 tons per hour and can be operated by four men. With four or five of these machines a vessel of 6,000 or 7,000 tons can be unloaded in less than a day without the least trouble.

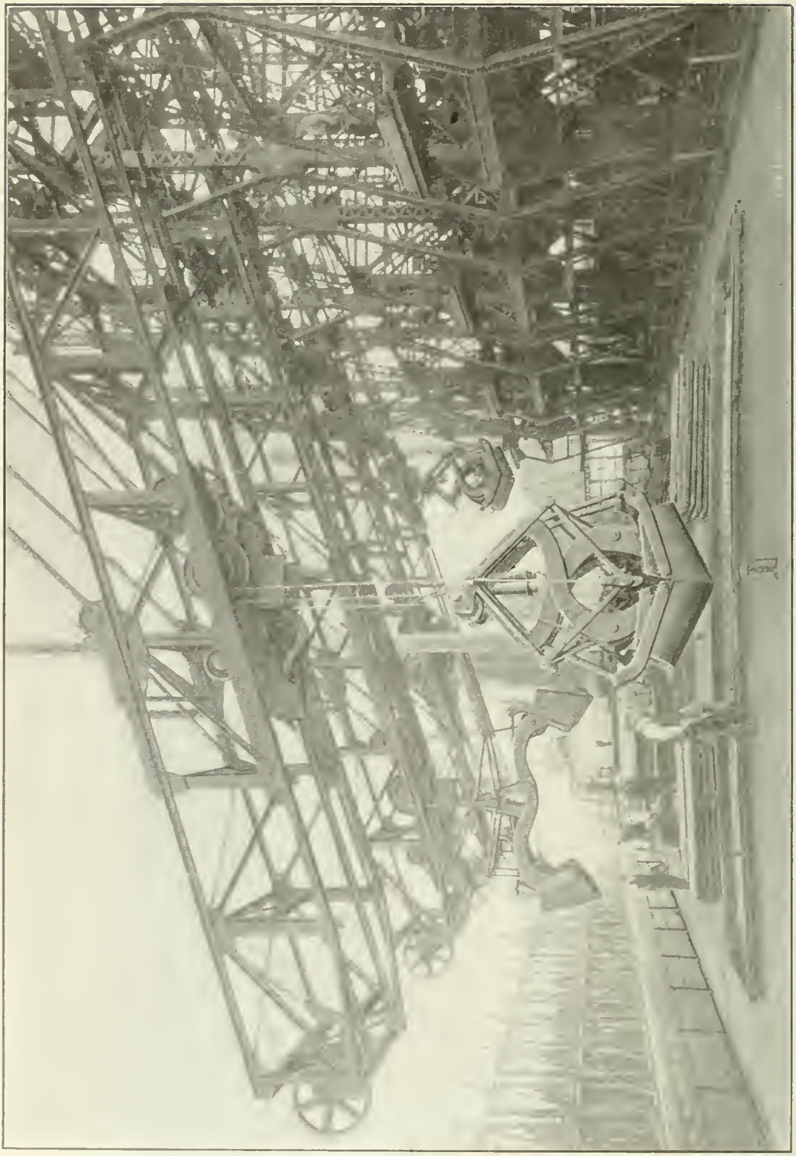
The very newest unloading machine that the writer has been able to learn of, which is in successful operation, is that made by Messrs. Hoover & Mason, of Chicago. This machine, while bearing more resemblance in a general way to the bridge tramway type of machine than the Hulet machine does, has many strikingly new features, which bid fair to give it a prominence not yet attained by any other unloader that has preceded it. The most complete plant of Hoover & Mason machines now in use is that on the docks of the Illinois Steel Co., in South Chicago. They also have machines in operation in Cleveland, Ashtabula, and other places.

The illustration shows a general view of the South Chicago plant at work unloading a vessel. This type of machine has the conveyor for carrying the ore back to the stock piles separate from the unloader. This is quite a step in advance in an economical way. There are fourteen unloaders and two bridges. The distance from the end of the apron over the ship to the extreme back of the bridge is about 580 feet. The aprons can be raised to let the vessel in close to the wharf and then lowered over the hatches of the vessel.

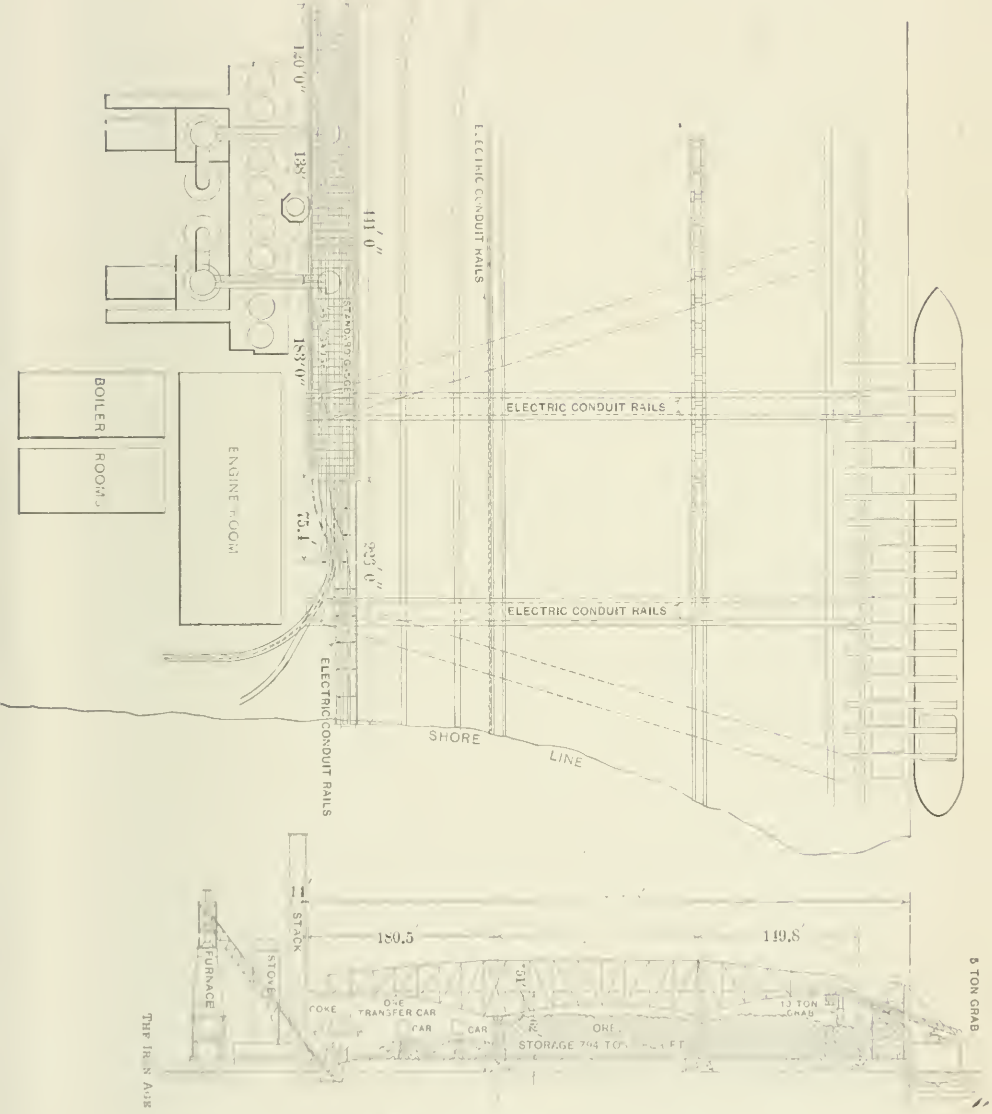
These unloaders can be moved along the dock much the same as the other machines that have been described, and resemble the direct unloader in a general way. Under the end of the unloader away from the dock is situated an immense V-shaped trough that will hold the contents of any vessel on the lakes. The ore that is to be placed in the stock piles is dropped from the unloader



Hoover & Mason Unloader, showing Masonry Trough.



Hoover & Mason Unloader;—view of Grabs, open and closed.



THE IRON AGE

Hoover & Mason Unloader, South Chicago.

buckets into this trough, and afterwards taken out by means of the bridge bucket.

When the aprons are down over the vessel and all is ready for unloading, a five-ton grab bucket, carried by a trolley, is lowered into the hold. This bucket is one of the principal features of the plant, and is accomplishing what other inventors have tried for years to acquire, namely, a grab bucket that would automatically fill itself with ore. The Hulet bucket does this, but only by being held down to its work by the immense walking beam; but this machine has a bucket that in closing, automatically fills itself with five tons or more of ore. This bucket when open has a spread of about 12 feet, and can be swung around in the vessel so as to take out about 60 per cent of the cargo without any hand shoveling whatever. After this amount has been removed, scrapers are put to work between the hatches, by means of which the ore that the bucket could not reach can be scraped from the edges into piles under the hatches where it can be caught by the grab bucket. These scrapers are drawn back and forth by means of a wire rope from the hoisting engine.

The bucket is carried by two independent sets of wire ropes; when one set is tight and the other set is slack, the bucket is held open, and is then lowered upon the pile of ore. The first set is then let slack, and the engine begins pulling at the other set, which are arranged to close the bucket without withdrawing it from the vessel. This bucket works very rapidly and successfully. When the bucket is up and out of the vessel it is carried back and either dumped into cars standing under the unloader, or into the concrete trough already mentioned.

In this way a vessel of 6,000 or 7,000 tons burden can be unloaded in 13 or 14 hours, including cleaning up, at a total cost per ton which it is claimed will not exceed 3 cents. When the ore is deposited in the concrete trough it is out of the way and can be removed and placed in the stock piles at leisure. To accomplish this, two immense cantilever conveyors mounted on trucks have been constructed, spanning the storage yard. These bridges move up and down the whole length of the trough, and can be slewed to any desired angle across the yard. On the runway of these bridges is an electric traveler, which goes the entire length of the bridge. Depending from this is a grab bucket very similar to the one described in connection with the unloader, except that this one grabs ten tons instead of five. With this bucket the ore is taken from the trough and carried wherever it is needed in the yards. One man who rides in the trolley controls the operation of these conveyors.

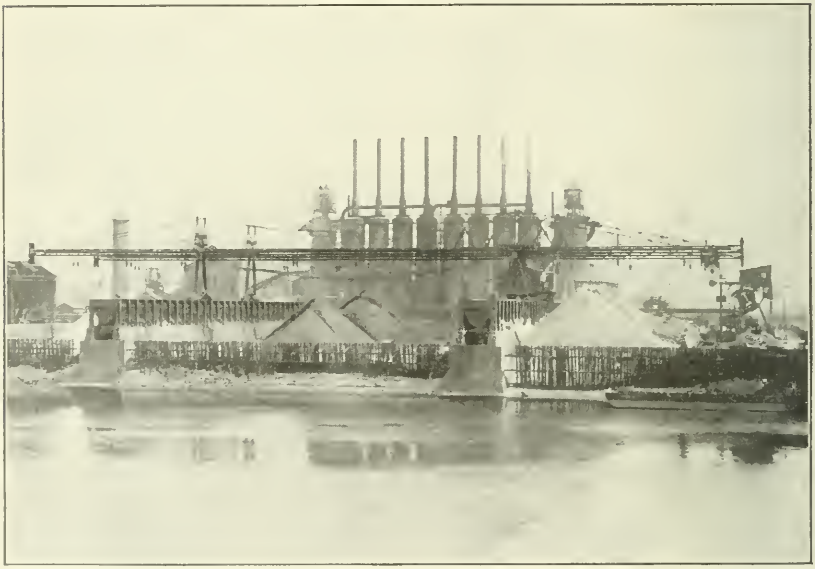
The statement made earlier in this paper, that unloading machinery is only in its early stages of development has been verified by what has been shown, if these newer machines prove themselves as efficient as their promoters maintain they will. And in passing I would reiterate my former opinion that within a very few years every style of unloader now in use will have become a back number. In the Hulet machine there is too much bulk of machinery in motion for the amount of work done, and unless this machine is very greatly simplified I doubt its general introduction among the docks. If some sort of rapid endless chain conveyor were devised, that would carry the ore up out of the vessel and back upon the dock, rapidly and continuously, it would seem to me that one-third of the machinery would do the work better and faster than is now done.

That the improvement in unloading machinery has been slower than the improvement in other branches of ore transportation cannot be denied, but from the foregoing it is plain that there have been great strides in the right direction. With the method of fifty years ago the ore was lifted from the hold in wooden tubs, dumped into wheelbarrows and wheeled back along runs to the stock piles and dumped, to be again handled before it was ready to start inland. When a vessel tied up to unload, although the largest vessel carried scarcely 1,000 tons, it was with the expectation of staying weeks instead of hours. It must not be forgotten that the nominal saving in rapid unloading is only a part of the actual saving made possible by these new methods. The great saving in wharf room, that will permit a dozen vessels to unload in the space where one did formerly, is no insignificant item. Also the immense capital invested in lake vessels should not be lying idle in harbor during the summer season. The interest and insurance on a large lake vessel with the wages paid to seamen will easily amount to $100 to $150 per day.

Very recently another innovation has been introduced to avoid delay. Until within a year or so ago, when a vessel had discharged her cargo, she had to put into a coaling dock to coal for her trip back to the mines. Now there is being introduced a mammoth "fueller" which obviates this delay. This fueller is a large self-propelling barge with pockets for carrying 200 to 300 tons of coal. When a vessel ties up and begins to unload, one of these fuellers comes alongside and transfers 200 or 300 tons of coal from its pockets to the bunkers of the vessel. This transfer is made by means of a crane and a two-ton bucket.

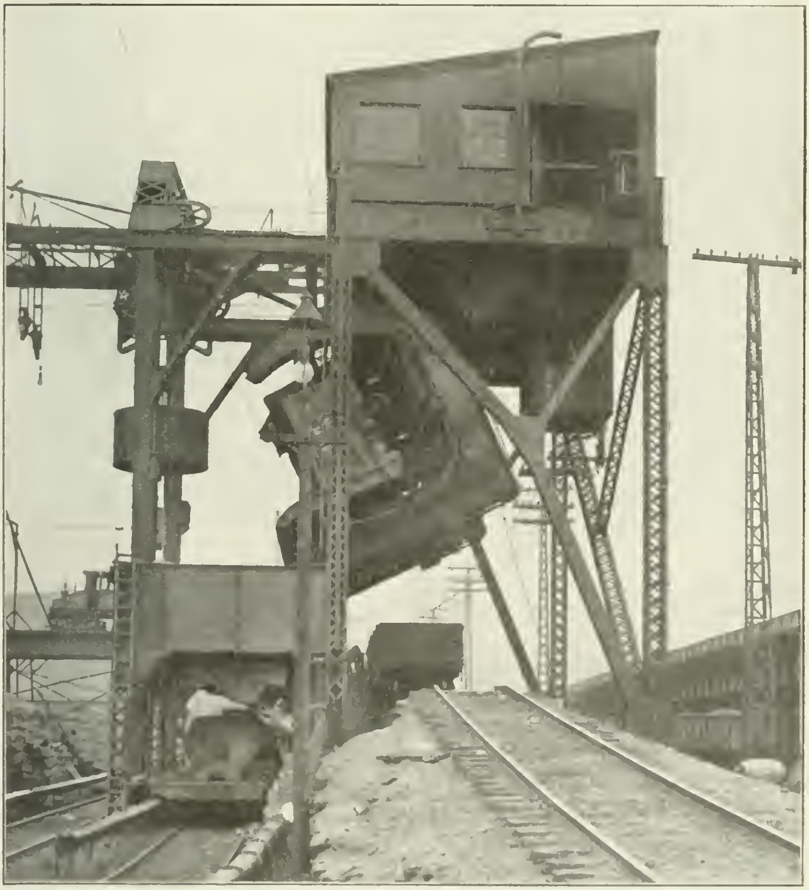
Now that we have made the journey from the mines to the lower lake docks, and have seen the ore as far as the stock piles or in cars ready to be distributed inland, we will let the Storm King rage and the lake freeze over while we wander inland, following the course of the ore to the furnaces.

As the P., B. & L. E. Ry. is the best equipped ore-carrying road in the world, or elsewhere as far as reported, it is worthy of an examination. The cars weigh about 17 tons and carry 50 tons. The locomotives weigh 217,000 pounds and can haul a train of 35 or 40 loaded cars, making a total load including dead load of engine and cars of 2,600 tons. Every equipment of the road is of the most modern design and the freight rates very low. When the ore trains reach the furnaces they must be unloaded as quickly as possible in order to save cars and to save storage room. It is surprising how soon the yards will become clogged, and a car famine will occur, if anything happens to prevent unloading.

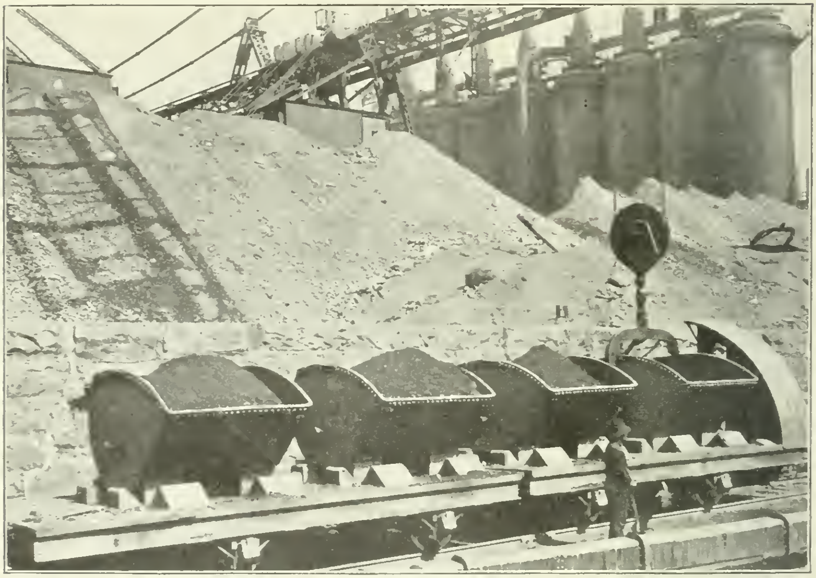


At the Carrie furnaces of the Carnegie Steel Co., at Pittsburg, there has recently been put into operation what is without doubt the largest and most efficient car-unloading and storage plant ever built. This plant was designed and built by the Brown Hoisting Machinery Co., and represented, when put up, their most advanced ideas in this direction. As we said, the P., B. & L. E. Ry. is equipped with hopper cars which unload from the bottom, but as the ore "arches" badly and is hard to get out, this method was not satisfactory. And as there are still in service hundreds of ordinary coal cars, it was necessary, in order to avoid all delays, to install a car-dumping machine to unload these. The illustration shows a general view of the plant from the river bridge. To the right is the car-dumping machine and the switch yards. In the center of the picture can be seen the two double cantilever bridge tramways, 550 feet long, the storage yards, the storage bins, and the furnaces in the background.

The car-dumping machine is placed at one side of the switch yard, and in such a position as to readily receive the loaded cars which approach from the opposite side in the view. The cars of ore and limestone are switched in upon the unloader track in the order in which those materials are required at the bins. A locomotive is then put behind this string of cars which pushes the cars upon the unloader platform. When a car is upon a platform it is clamped down to the track. The machinery is then set in motion by the operator stationed in the engine house above, which picks up a section of the track, car, load and all, and quietly turns it through nearly a semi-circle, pouring the ore out into a hopper. This bin



or hopper holds a hundred tons of ore and is provided with gates at the bottom through which the ore is let out into the bucket cars. When the car is dumped and back again on the track in its normal position, the next loaded car is pushed in, which pushes the empty car off the tipple. As soon as the empty car is off the tipple platform it runs of itself down the graded track and across a spring switch, and is stopped by a steep-ascending grade, which in addition to stopping it gives it a start in the opposite direction. It then starts back toward the dumper, is automatically switched off and passes around the side of the machine and runs down a grade to the storage yard for empties.



After the ore has been dumped from the railroad cars into the hopper, a pair of motor cars carrying four immense buckets is pushed in under the bin and the ore is let through the gates into these buckets. The bucket cars are afterwards switched in upon the transfer tracks and stopped under the cantilever; the hook block from the trolley with the bucket bale attached is lowered, the bale attached to the bucket and the bucket lifted from the cars and carried back to wherever the ore is required. These buckets carry ten long tons of ore, or a total load of about thirteen tons, and are self-dumping and self-righting. These loaded buckets can be lifted at a speed of about 250 to 300 feet per minute, and the trolley with its load will move across the bridge at from 800 to 900 feet per minute, or about ten miles per hour. Again referring to the general view it will be seen that one of the cantilevers is just in the act of raising the bucket from the car and the other has one up ready to start back. When the ore accumulates at the dumper faster than it is required at the furnaces, it is piled in the storage yards as shown. These storage yards have a capacity of about 500,000 tons and are intended to provide ore for use during very bad weather, or at such other times as it would be impracticable to supply the furnaces direct from the cars. When the furnaces are being supplied from the stock piles, the ore is rehandled by means of a shovel bucket which is operated from the bridge tramway.

The ore and limestone are deposited in parabolic bins under the tracks of the bridge tramway. These bins are divided into compartments in which ore of different kinds and the limestone may be kept separate. A small electric suspended car runs beneath these bins their whole length and back to the furnaces. The proper proportions of ore and limestone are automatically weighed into these cars and then carried back to the coke bin, where the coke is added, when the load is then ready for the furnace.

When the ingredients have been properly weighed and mixed they are dumped into the furnace skip, a small car which carries the material to the top of the furnace. A larger detail of the skip is shown near the top of the incline. It will be noticed that the back wheels are double-flanged, while the front wheels are not. As the skip approaches the top of the incline the front wheels follow the track they are shown on, which bends in over the top of the furnace, while the back wheels are caught by a wider-gauged track and carried on up. This action turns the skip nearly upside down and allows the contents to pour into the furnace.

The supreme object of all cunningly devised machinery is the reduction of the amount of hand labor required and the saving of time, which in the end means a reduction of cost. The pictures have explained in themselves, in a large measure, the reduction in numbers of men employed. How time has been cut down may be realized when it is known that with modern appliances, within ten days from the time the ore is taken from the mine it can be piled up as finished steel in Pittsburg. Or to show how far the ways have been smoothed over which the raw products glide to reach each other, a Cleveland mill owner could promise to deliver steel in ten days, when at the time of signing the contract the ore was in the Superior mines in its native bed, the coke still in the ovens in Connellsville, Pennsylvania, and the limestone in the quarry.

## DISCUSSION.

*President Finley*—While Mr. Hatch has described the development of machinery in the handling of ores at the mines and on the lakes, he has said little about the developments in carrying the ores from the mines to the docks and loading it in vessels there. I think the methods employed now are about the same as those used thirty years ago, and that there is very little improvement in the cars or the docks of the railroad companies for handling the ore before loading it in the vessels.

I would like to ask Mr. Hoover if he will not tell us a little about this.

*Mr. Hoover*—I prefer not to enter into discussion of Mr. Hatch's paper. I have enjoyed this lecture very much and I think the Society is greatly indebted to Mr. Hatch for the able manner in which he has handled the subject.

*President Finley*—I would like to know, Mr. Hoover, your opinion as to whether the railroad companies have kept pace with these other improvements?

*Mr. Hoover*—If I were to give my opinion it might reflect on some of the railroad officials who may be members of this Society, and perhaps some of the officers. I think the President has very aptly put the question — they have not kept pace — but it would certainly not be courtesy in me to make that statement, although it may be correct to state it, and his honesty is certainly commendable.

*President Finley*—I would like to ask Mr. Pratt if he will not take part in this discussion?

*Mr. Pratt*—I am sorry to say, Mr. President, that I have not had enough experience in the methods of transporting ore or unloading vessels to say anything.

*A Visitor*—I should like to ask Mr. Hatch if anything has been done in the way of continuous conveyors for unloading vessels?

*Mr. Hatch*—There have been several methods tried for unloading coal, but I do not know of any successful conveyor of that style now in operation.

*A Visitor*—What kinds have been tried?

*Mr. Hatch*—I do not know, only from pictures I have seen. They are a string of buckets on a chain similar to the elevator buckets used by Hunt for conveying coal to the boilers in such places.

*A Visitor*—Referring to the concrete trough into which the ore is dumped after it is taken out of the boat, I would like to ask how the ore is taken out of this trough?

*President Finley*—I will ask Mr. Hoover if he will not answer that question.

*Mr. Hoover*—The trough is made V-shape so that the bottom will conform to the shape of the trays of grabs, so that the grab will clean up the trough practically without any manual labor. The grab opens up lengthwise of the trough and the trough converges so that the grab will clean it up entirely.

*Mr. Hatch*—The slope of the trough is greater than the natural slope of the ore, is it not?

*Mr. Hoover*—Yes. It cleans itself and the ore generally slides down without any assistance. Occasionally it needs a little assistance.

*Mr. Tratman*—I would like to ask if all of these different types of unloaders are now being made?

*Mr. Hatch*—These are all being made at the present time. The unloaders I showed—the bridge tramway and the direct unloaders—are the oldest style and they are the standard, for all the companies that make them. The bridge tramway is the standard of the Brown Hoist Co. They probably make more of these than of any other style of machine. None of the machines I showed are out of date at the present time. It has only been five or six years since anything better than the bridge tramway was made. That is not out of style and is the oldest machine I showed; it has been perfected for about 14 or 15 years.

*Mr. W. S. Love*—I would like to inquire if there is any way for the ore to be weighed on its way to the receiving docks at Pittsburg?

*Mr. Hatch*—Do you mean before it is unloaded from the vessel?

*Mr. Love*—You said that the vessel carries ore as high as 8,000 tons. Was that estimated measurement, or is it weighed in the vessel, or how is it done?

*Mr. Hatch*—It was estimated, as far as I am concerned. I do not know whether there was any accurate way of weighing or not.

*Mr. Love*—They must charge up the freight on some basis if they charge the freight on tonnage.

*Mr. Hatch*—I would think that from the water line, or immersion of the vessel's hull, they could judge accurately—at least close enough for freight rates. I do not know exactly how they do it.

*A Visitor*—My understanding is that it is weighed on track scales at the docks, and the railroad companies keep very accurate account of the weight of ore that goes into each pocket. At Ashland the railroad companies mix the different grades of ore as ordered by the furnace men.

*President Finley*—The railroad companies weigh all ores coming to their docks on track scales. I have had occasion to check up some cases and they always overrun the rated capacity of the cars.

# CLVIII.

# THE YAZOO DELTA OF MISSISSIPPI AND LOCATION AND CONSTRUCTION OF ITS RAILROADS.

By J. N. Darling, M. W. S. E.

*Read Oct. 22, 1902.*

The Yazoo Delta of Mississippi extends from about the south line of Tennessee, southward to Vicksburg, Miss. It is bounded on the west by the Mississippi River, and on the east by the hills of the State. These hills, though scarcely exceeding in any case 80 or 100 feet in height, form a well defined and prominent boundary to the low and flat country of the Delta.

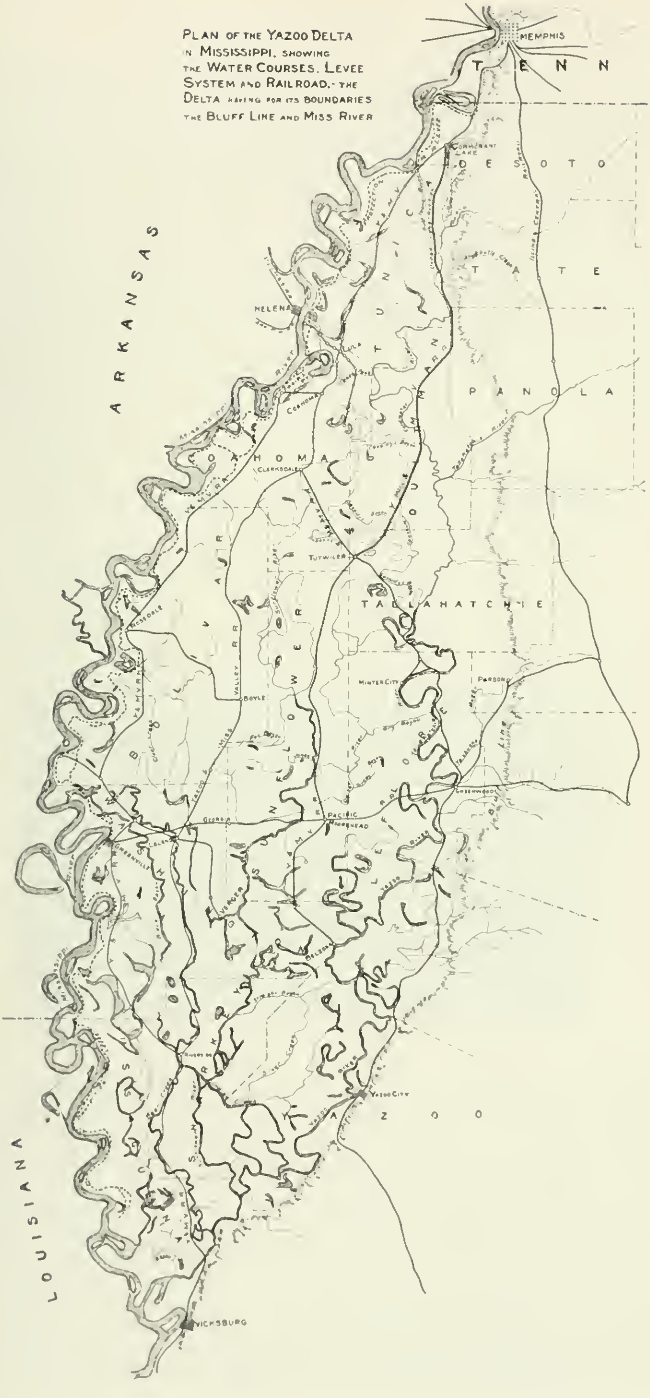
The extreme length of this flat country, from its most northerly to its most southerly point, is about 180 miles; and its greatest width, which is about midway of its length, is 66 miles. Its total area is about 7,500 square miles.

This vast extent of country was, until comparatively recent geologic times, a part of the Gulf of Mexico, when, according to geologic maps, the Gulf extended as far north as Cairo, Ill., the mouth of the Mississippi River being then at that point. It has since become gradually filled up by sedimentary accumulation from the great river, at flood; the reduction in the rapidity of the current, owing to the spreading of the water, causes the sediment to drop, and causes this most rapidly as the water is leaving the banks of the parent stream.

The general slope of the Delta, is, of course, southward. It having an elevation of 218 feet at its upper, or northern extremity; 185 feet on the bank of the river at Friars Point, 45 miles to the south; 138 feet at Greenville, 110 miles to the south; and 95 feet at Vicksburg, its extreme southern point. This gives a total fall of 123 feet in 180 miles of distance, or 0.68 feet per mile. The elevations here given are all referred to Memphis datum, which is 8.13 feet below the mean level of the Gulf of Mexico.

It is to be noticed that the rate of fall mentioned, would not represent that of the Mississippi River, as that stream in its tortuous course from Memphis to Vicksburg probably measures two or three times the 180 miles mentioned.

As might be expected from the manner in which this low country has been formed, namely, by sediment from the Mississippi River, the slope or fall is eastward as well as southward, and from (rather than toward) the river. The general surface elevation at Friars Point on the river, is, as before stated, 185 feet; while 20 miles to the east of this point the elevation is but 160 feet. In other words,



PLAN OF THE YAZOO DELTA IN MISSISSIPPI, SHOWING THE WATER COURSES, LEVEE SYSTEM AND RAILROAD.- THE DELTA HAVING FOR ITS BOUNDARIES THE BLUFF LINE AND MISS RIVER from the river, eastward to the hills, the fall in this portion of the Delta, is about 1 ¼ feet per mile—a more rapid fall than that from the north to the south. This comparison shows the general contour of the surface of this low country. The surface thus sloping away from the river, there are of course no rivers running into or toward the Mississippi.

Between the Nonconnah River (which flows into the Mississippi River directly from the hills, two or three miles south of Memphis) and the mouth of the Yazoo River, which flows into the same river at Vicksburg, it has been possible to build one continuous levee to protect the vast bottom country from annual overflows from the Missisipppi River. The levee varies in height from 10 to 35 feet.

A Shipment of Logs.

This protection levee begins at the base of the hills just south of the Nonconnah River, and follows the general course of the Mississippi, extending southward nearly to the mouth of the Yazoo River, which river with its tributaries, running through the east part of the bottom country, forms the east drainage system of the entire delta, all of whose waters find their way finally into the Yazoo River. Between this river and the Mississippi River the entire extent of country is traversed by a network of bayous, which are mere gullies or channels in the silty soil (in some cases of considerable depth), whose waters remain stagnant or flow indifferently in either direction, dependent in their flow on varying local conditions. These bayous have, in general, an easterly and southeasterly course, and discharge their surplus waters toward the Yazoo River and its tributaries. Many of the larger bayous, previous to the construction of the present system of protection levees, had a mouth or opening into the Mississippi River itself, and at flood of this river served as by-passes to carry its waters eastward across the bottom country to the tributaries of the Yazoo River, thence by the latter river to the Mississippi River again at Vicksburg.

The principal bayou or by-pass of this character is the so-called Yazoo Pass, which, previous to the construction of the levees, was a fine navigable channel at high water for flat boats plying between the Mississippi River and the rivers of the Yazoo system. Through this pass Gen. Grant in the time of the Civil War took some transports in an attempt to reach Vicksburg with his troops by way of the Yazoo River. The attempt, however, proved futile and he was obliged to turn back without reaching the latter river. This pass is now shut off from the Mississippi River by the levee, but is still navigable for small flat boats at high water.

A point to be noticed with reference to these larger bayous is the fact that the surface of the ground slopes from rather than toward them. This shows what the waters of the Mississippi, the Yazoo and other rivers have done and are doing at flood, raising the surface of the country with their silt, and what more rapidly near their banks these smaller water courses are doing in a more humble way.

This Delta country is in its primitive condition, a dense wilderness of oak, cypress, gum, ash, hickory, etc., trees which, under a southern sun and nourished by a soil of great fertility, attain a great size. The trunks of the oak and cypress oftentimes attain a diameter of six and even seven feet. On the lowest ground most remote from rivers or bayous, is found the cypress, valuable for railroad structures and for ties; while the oak at its best is found on the relatively higher ground.

In all this wilderness, which is not subject to long continued overflow, a dense growth of cane is found. This is in some cases so dense as to be hardly passable by any animal except the bear, which, as well as the panther, wolf and deer, is still found in these wilds.

Previous to the Civil War, and until the annual overflow was shut off by the levees, little in the way of cultivation was done or attempted in the bottom country. It was looked upon as too unhealthy for the whites, and after long months of overflow it must have been malarial in the extreme.

It is true that even before the Civil War some progress was made at settling up this country. Men with a surplus of slave labor came in from the surrounding country and made beginnings at opening up and subduing the wilderness, but many movements of this kind were stopped by the war. Much land that had been partly cleared was allowed to go back to its wild state again, and little substantial progress in the way of settlement was made until after the war. There are now, however, some thousands of square miles in full or partial cultivation, and the timber and crop products of this fertile country furnish a profitable carrying trade for the railroads now built.

There are within the limits of the bottom country, about 750 miles of railroad in operation, 100 miles belonging to the Southern system and 650 miles to the Yazoo & Mississippi Valley system. The latter company has also about 100 miles additional nearly completed, and other extensions in prospect, all within the limits of the Delta.

A Canebrake.

The difficulties attending the location and construction of these extensions are not, generally speaking, technical, but are those that have to be met by such common sense and judgment as the engineer may be so fortunate as to possess.

Here, as in all cases where a new line or an extension is to be built, the authorities wish to have the country examined, and a report made as to the probable cost, etc. If this examination is called for in the summer, the engineer has to force his way through the dense forest, fighting mosquitoes and all the other myriads of insect life that combine to make life a burden. What little attention he has to spare he uses in viewing the country through which he passes. If the work is to be done in winter, he has mud and water, instead of animal life, to bar his progress.

Whether the examination is made in summer or winter, little can really be seen on either side of the path traversed, owing to the ever present cane, which prescribes narrow limits to the range of vision. Hence the knowledge gained from the reconnoissance survey is of a very vague character. We are expected, however, to first make this kind of a survey, and then talk wisely thereon. Our reports stand unchallenged until their unreliability is revealed by the location survey, if one is made.

The reconnoissance survey, however, though it may fall far short of what is expected of it as a means of enabling the engineer to form a close approximation as to cost, is of use in enabling him to form some slight acquaintance with the general character of the country traversed, and thus enabling him to proceed the more intelligently with the instrument survey, when it is made.

It enables the engineer to plan in advance how best to get through the country with his party, his supplies, etc. But the only way to make an intelligent estimate as to the cost of the line is to run an instrument line; and then, with this as a base line, traverse the country on either side, slowly and laboriously. Then from this base line, project a location that will fit as nearly as possible, the conditions encountered. An estimate on this projected line, if carefully projected, should give a tolerably accurate idea of cost.

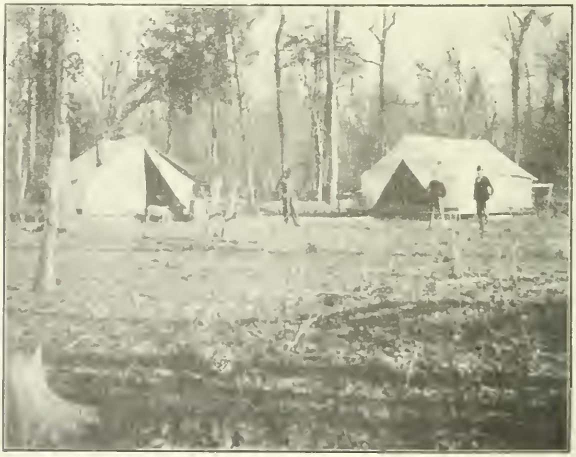
The cypress brakes of this country are among the most formidable barriers to railroad location and construction, their dense growth of trees, of enormous size at the ground, with cypress "knees" occupying all the intervening space, and with standing water most of the year making railroad building very difficult and tedious. Indeed, the sight of a mass of cypress tree tops in the distance is a warning to the locating engineer to deflect from his course, if he is headed toward them. We oftentimes build through these brakes of course, but not if we can well avoid them.

The reconnoissance through this country is rendered more difficult by the numerous bayous, sloughs, etc, by which the country is intersected. If the trip is made on horseback, wide detours have often to be made in order to get around or across one of these obstacles, or to cross some river; and much time is consumed in getting around to the course again. With no land marks or inhabitants to help the engineer, the recovery of the course, once lost, is exceedingly difficult.

If the reconnoissance is made in cold weather, a journey on foot can be made more quickly and effectively than on horseback, as less time is lost in making detours, especially if the engineer is willing to take to the water and mud as he comes to it. In the summer season, however, the excessive heat in these forests makes a foot journey too exhausting for the ordinary engineer.

In making a location survey, it is necessary to equip a party of about 18 men for advantageous work: a transitman, a levelman, one rodman and two chainmen, all white and of technical ideas, if possible. The remainder of the party will be made up of the best negroes that can be found. These negroes made good axmen and chainmen, and some of them make active rodmen in cases of emergency. A special advantage in having plenty of negro labor, is the fact that the negro is more easily provided for, and less liable to sickness from hardships and the unhealthy climate than the white man.

Engineers' Camp.



There being no resources in the wilderness for the support of a locating party, it is necessary of course, to equip with a complete camping outfit; about four tents, a cook, cooking utensils and plenty of substantial food stuffs, consisting of ham, bacon, side meat, beans, dried apples, dried prunes, etc. One or two teams and a saddle horse are also indispensable. The teams are kept busy moving camp, and going out of the wilderness for supplies, as these run short. In wet weather it often requires 12 mules to move one locating camp through the mud of these bottoms. With a locating party of the size mentioned, 1 1/2 miles of line is a good day's run, with eight and ten men cutting out the line.

Grading.

In going from location to construction, it is usually found best to divide up the work in short residencies of from eight to ten miles in length, so that the work of construction can be readily covered and looked after from a centrally located camp, on foot. The use of the team is to be avoided as much as possible on account of the scarcity or total absence of passable roads.

With heavy clearing, and (after the clearing is done) a heavy material for making the banks, the work of construction in the bottoms is slow and tedious. A party of three or four men is found large enough for keeping up with the work of a residency. Each construction party is provided with two or three tents, a cook, and all the requirements for independent living. Thus provided for and housed, they camp in the woods for a lonely stay of usually several months until the work of construction is completed.

In the summer season little difficulty is experienced in getting the earthwork done with teams, drag and wheel scrapers being used to bring in the earth from side borrow pits. As the wet weather of winter comes on, the ground gets so wet and sticky that in order to continue the work it becomes necessary to use the "hobo" with shovel and wheelbarrow, in order to keep the work going. In overflow land, grading, even by this method, often becomes impossible. In this event, work has to be abandoned until the dry season comes on.

Trestle building.

In this flat country the water usually flows with so sluggish a current that the pile trestle usually answers all purposes for drainage and for water courses. At river crossings, however, span bridges have to be used, as the rivers carry too much drift in high water to allow of trestling. The pile penetration necessary for substantial work is usually 18 or 20 feet, although in exceptional cases a penetration of 25 or 30 feet is found necessary.

Owing to the impassable nature of this Delta country, which makes transportation of bridge material, except by rail, next to impossible, our trestle bridges are usually driven from the track and by a track pile driver. The work of pile driving is done from the end of the last rail. By doing the work in this way, the material is transported to the work without difficulty and at a minimum cost. At openings in low banks, the track gang "cribs" over, and the pile-driver follows up with the driving; but where the trestle opening is deep and long, the pile-driver comes up and drives the opening, the track gang meanwhile working at back-spiking, loading rail, ties, etc., and thus the two kinds of work are carried on together.

The sub-foundations for all span bridges, where masonry is used, have to be compacted with piles; these are driven as low as possible, and cut off below low water; on and between these the masonry (usually concrete) is built up.

The pivot pier to a drawbridge now being built over Coldwater River, by the Illinois Central Railroad, is supported by 69 piles with a penetration of about 25 feet. The superstructure resting on this pier is 134 feet feet in length, supported at its outer ends, when closed, by cylinders, which are sunk down over clusters of piles to solid bearing and filled with concrete.

Crossing of Coldwater River.

Owing to the comparatively slow current of the water in the bayous and rivers of the Delta, a smaller drainage capacity than for an equal amount of water in a hilly country answers for drainage. For example, the Coldwater River where it flows under the Illinois Central Railroad in the hills of Mississippi requires a drainage cross section of about 16,000 square feet. Passing down this river 50 miles to where it flows under the road recently constructed, from Tutwiler to Lake Cormorant, 10,000 feet of drainage cross section is sufficient. Going down the river 100 miles farther to where it flows a second time under the same new road, 6,000 feet of drainage section is ample to carry the water. This anomaly is doubtless due, in part, to the slackening current, and also in part to the fact that the river at flood spreads out into the bayous and over the bottom country, and there waits until it has an opportunity to flow leisurely on its way.

Shipping Point for Staves.

To speak briefly of the utility of railroads in this Delta country, railway extension is the only factor that makes a general development of this country possible. In the rainy season the wagon roads are well nigh impassable, and a long haul by wagon through the alluvial mud of this country is, and will continue to be, out of the question. Hence the great importance of railroads at short intervals. And the Delta is so rich in its products of timber, in its first stages of development, and of farm products at a later stage, that it will support a large railroad mileage, if built at not too excessive a cost. As the cost of these roads does not usually exceed $20,000 per mile, it is financially practicable to give the Delta a large railroad mileage, and the settlement of this fertile country and railroad extension can go hand in hand.

DISCUSSION.

*Prof. W. D. Pence*—I would like to ask whether the track is in all cases above the overflow level.

*Mr. Darling*—It is intended to be, but sometimes it is not. It is usually the case that we get above the overflow level unless we want to build very cheaply at first cost and then raise the grade later. Sometimes we do that. The roads now being built are all laid as to grade line above high water. There was a high water in 1882, at which time the Delta country was practically all overflowed by breaks in the levees; there was another high water in 1897, but not quite so high as in 1882. There was a local high water last spring when the flood was as high as in 1882, at which time between eight and nine inches of rainfall came within a week. That was the first of last April. We are laying grades now above that in that portion of the Delta.

*President Finley* In one of the pictures I noticed the center pier for a drawbridge. It did not look to me as if there was much of the river left for navigation.

*Mr. Darling* At that point there will be about 50 or 60 feet of clear channel.

*President Finley*—On one side?

*Mr. Darling* Yes. That drawbridge is 134 feet in length. The diameter of the pier is 18 feet; that will take off 9 feet from 66, leaving about 55 feet clear space between. That is enough for any navigation on that river. There is a bridge about to be built over the Yazoo River, in which the span is to be 220 feet and the pier is to be 22 feet in diameter. Half of that off the half of 220 feet leaves about 100 feet clear space for navigable channel.

*A Visitor* I infer that your alignment must be very straight if you could keep your construction work up so near the locating line.

*Mr. Darling* I think I must have been misunderstood as to that. We usually complete the location before the construction work begins; we have to do that on account of the preparatory work that has to be done on securing the right of way, etc. There, as elsewhere, if we get the construction work too close to the location, we work at a disadvantage when we attempt to secure the right of it.

*Prof. Pence* I would like to ask Mr. Darling his opinion of the relative merits of building a low-level line which may be submerged but which will not be washed out during flood periods, and a high-level line, which may have insufficient water-way and be washed out.

*Mr. Darling* If the use of the road could be dispensed with when the flood is on, it might be advisable to use a low-level grade. These grades do not wash very much.

*President Finley* I should not imagine there was as much difference down there where the current is slow as in the western countries where we have a swifter current; that is, the difference between low and high-level lines would not be affected very much in the Delta conntry by those conditions.

*Mr. Darling*—When the heavy rainfalls came last spring the roads were suffering in the hills from losing their grades by washouts. There were no washouts in the Delta country, where the current is not so swift. The Illinois Central ran the through trains at that time through the Delta country until they could repair the main line through the hills.

*A Visitor*—About what is the difference between high and low water?

*Mr. Darling*—It varies from 20 to 40 feet, measured from the low water level in the Yazoo and other rivers.

*Mr. Benj. Wolhaupter*—What do you use for ballasting?

*Mr. Darling*—There is a poor grade of sand in the Delta country, that has been generally used. The main line of the Yazoo and Mississippi Valley Railroad has been ballasted up by a rather grade of gravel from Gloster, Miss., and the hill roads have been ballasted with Brookhaven gravel. A cementing constituent cements it somewhat. Lately we have gotten hold of a very good grade of *loose* gravel mixed with sand. We are glad to get hold of anything of that kind.

*President Finley*—Are those levees you speak of the Government levees?

*Mr. Darling*—Yes.

*President Finley*—Have they been effective in preventing overflow?

*Mr. Darling*—Yes, they prevent entirely the overflow. A levee broke in 1882 and again in 1897. Since 1897 there has been no overflow from the Mississippi River.

The overflow of the Delta country at the present time is due to overflow of the Yazoo River and its tributaries. This will always take place in a rush of water. It looks to me as if sometime, in the not far distant future, there would be further overflows from the Mississippi. Engineers, however, have different views on this matter. The Mississippi is all the time filling its own channel at some points at least.

*President Finley*—Where the Yazoo River is dammed off, what takes care of the flow that went down through that opening where you say it is now shut off?

*Mr. Darling*—That is the Yazoo Pass leading ultimately into the Yazoo River; the upper end is at the bank of the Mississippi River. That is, the head water is at the Mississippi River, the Mississippi River banks being higher than any of the country east.

*Mr. Wolhaupter*—I notice you get out a great deal of timber. What class of timber is that?

*Mr. Darling*—The best timber to be gotten there is white oak. Red oak, however, is gotten out now in large quantities on account of railroad facilities. Ash, hickory, cypress and cottonwood are also used.

*Mr. Wolhaupter*— Is the white oak raised on that low ground?

*Mr. Darling*—Yes.

*Mr. J. H. Warder*—Does all that land belong to private owners, or is some of it state land?

*Mr. Darling*—Very little is state land. In many of the counties there are certain sections which are Government school land. Only a leasehold can be acquired tor that. The rest belongs to individuals or syndicates.

*Mr. Warder*—Do you have any trouble in getting a right of way?

*Mr. Darling*—In that remote country they give us most anything to get us through, unless we get so far along that they can take advantage of the situation.

*President Finley*—You have the same experience down there that we have everywhere.

*Mr. Wolhaupter*—What use are they making of that country?

*Mr. Darling*—After they get the timber off they raise corn, hogs and cotton.

## CLIX.

# WATER WASTE AND ITS DETECTION.

By Edward S. Cole, M. W. S. E.

*Read Oct. 22, 1902.*

Economy is the watchword of today in all lines of business. Schemes for stopping leaks are adopted everywhere and they range from the cash register in a drug store, to the combination of competing industries. Today it is only necessary to point out a waste to arouse the keenest interest in its prevention.

With the rapid growth of our cities it has been difficult enough to extend water works systems so as to keep pace with the increasing demand for water. The subject of water waste has been neglected, and it has come about that many cities now find themselves providing an unreasonable supply with apparently no limit to the demand, which is increasing faster than the population. Eleven years ago the rate of consumption in Chicago was 126 gallons per capita, now it is 165 gallons, an increase of 27 per cent. Our city engineer, Mr. John Ericson, C. E., estimates the present waste of water to be 75 per cent of the entire pumpage. If this is true, it indicates a more serious state of affairs than is generally believed even by our most intelligent citizens. "It is impossible!" "Where can the water go?" Such remarks as these express a layman's first impression when the possibility of this enormous waste is presented. Think of our rate of consumption, nearly *four barrels* of water a day are pumped for every man, woman and child, and yet there are cities which have a higher rate than ours. Some will ask,—"Even if there is a waste of water what does it matter?" The answer is that in Chicago, for example, we are throwing away water which costs about *$19.50* per million gallons. This is based on the estimate of Mr. Rudolph Hering, C. E., and includes interest, depreciation, operating expense and maintenance on the entire water works system as it stands today. At this rate our water costs us nearly $2,500,000 a year. The receipts for water are in round numbers $3,400,000, leaving a net profit of about $1,000,000 annually. Now it is my purpose to show that the per capita consumption of a large city need not exceed 100 gallons daily, although the rate in Chicago is now 164 gallons per capita and in a number of other places it is still higher.

Before going into the evidence, let us see what it would mean to secure in Chicago a rate of 100 gallons daily use. Assuming the population to increase at the present annual rate of approximately 80,000, it would take 16 years for this city to exceed the present capacity of our water works system. The cost of the water would then be just the same as now, and assuming the present rate of revenue, which is about $1.70 per capita, the total receipts should be in 1918, 3,430,000 × $1.70, or $5,831,000, which, with the cost of production remaining the same as it is, would give a net income to the city of about $3,300,000 yearly.

Now on the other hand, if nothing is done to check the waste of water, the city will demand in that year a supply of fully 222 gallons per capita or 760,000,000 gallons daily; just about double the present capacity of the works. This is based on the reported increase during the past ten years of population and per capita consumption.

To double the present supply within the next 16 years, means an increase in fixed charges which will more than equal the increase in revenue received. In other words, the Water Department will operate at a loss instead of yielding a net profit of over $3,000,000 annually as it might within 16 years, provided public interest is aroused to support the necessary measures for waste prevention. As will be shown, a liberal use of water for all legitimate purposes can never equal the present rate of consumption in our large cities. No possible hardship is to be imposed on any one in stopping the leaks which undoubtedly exist throughout our system. But this enormous saving of the people's money can only be effected with the cooperation of the people themselves. Engineers have a remedy and it is a simple one, but without popular support the results would be difficult to obtain.

The possibilities of water waste prevention should now be sufficiently appreciated, and it remains to show: First, what we may reasonably expect to do; and, Second, how to do it.

According to recent water works statistics the per capita consumption in American cities varies between wide extremes. A few cities report as low as 50 or even 30 gallons per consumer daily; some use as high as 200 to 300 gallons, while, according to the tabulation of Mr. G. I. Bailey, of Albany, the average of 70 of the largest cities of the country having a combined population of over 12,000,000, use an average of 153 gallons per consumer daily.

The question arises as to the cause of this difference in the per capita use of water. First, there is evidently a great difference in the amount used for manufacturing purposes. Reliable statistics show the water used for manufacturing to vary from 2 per cent to 40 per cent of the total consumption. Second, it is found, that the higher the average scale of living in a city, the greater will be the domestic or household consumption. Much valuable information is at hand through the meter returns of cities, so that roughly speaking we may assume a tenement house to use from 5 to 10 gallons per capita daily and a dwelling house of moderate cost, with ordinary plumbing, from 15 to 35 gallons per capita, including lawn sprinkling; while the most expensive class of residences has been found to use from 40 to 60 gallons per capita daily.

Des Moines, Iowa, with a population of 62,000, has maintained a low per capita consumption of about 45 gallons for all purposes—domestic, manufacturing and public uses combined. The city has approximately 50 per cent of its consumers metered. It is interesting to note that there are in Des Moines 300 residences of average cost using less than 9 gallons per capita daily. In Columbus, Ohio, with 125,000 population, there are 8,000 meters, and among 2,000 of these taken at random from the books there are 650 with a daily consumption of less than 15 gallons per capita. This indicates that in fully one-third of all the houses in this city the per capita use is less than 15 gallons per day, based on the meter statements for July, 1902. These 2,000 meters averaged 65 gallons per capita daily. The total city consumption is about 100 gallons per capita.

A consumption of 10 to 15 gallons per capita daily has been reported by a number of water works superintendents as a fair average for metered residences.

The foregoing is but a meager summary of the data at hand regarding actual domestic consumption in cities under widely different conditions as given by actual meter measurements. A careful examination of all such figures which I have been able to secure leads me to believe that it is possible to form a fairly accurate idea of the reasonable consumption for domestic purposes in our cities. In other words, the domestic consumption of water need not be in excess of 30 to 40 gallons per capita daily, taking an average of all classes of houses. This figure would vary somewhat with the class of residences, as, for example, in the case of such a city as Fall River, where the homes of mill operatives largely predominate, we should expect a smaller house consumption than our standard of 30 or 40 gallons per capita.

Mr. Dexter Brackett, C. E., of Boston, reports an average domestic consumption of about 35 gallons per capita in a residence district of Boston containing 14,000 persons. In a valuable table of meter measurements in Boston, Brookline, Newton, Fall River, Worcester, Mass, and London, England, the average daily consumption per capita was found by meter to be 20 gallons for all classes of houses. The extreme variation was approximately from 6 to 60 gallons per capita, the higher figure being for expensive Boston apartment houses, and the lowest rate being for tenements in Newton having but one faucet. It is interesting to note that the rate in London was 25 gallons per capita for a residence district comparing well with the Fall River conditions, thus proving the consumption to be almost identical.

Of course, in matters of water supply our judgment must necessarily be based upon approximate data, but nevertheless I believe we now have sufficiently reliable statistics to establish the reasonable rate of domestic consumption. We must of course add to our reasonable domestic standard an allowance for manufacturing water, public uses and unavoidable loss at the pumps and in the distribution system.

Since the introduction of meters in our cities it is possible to analyze the total use and determine the percentage used for various classes of consumption. As a result of these statistics the following estimate was prepared by John R. Freeman, C. E., for the reasonable daily consumption in New York City, assuming waste of water to be largely restricted:

| | | | | |
|---|---|---|---|---|
| Commerce and manufacturing | 42 | gals. | per | capita. |
| Domestic and leaks in houses | 15 | " | " | " |
| Incurable waste in streets | 10 | " | " | " |
| Under-registration of meter | 3 | " | " | " |
| Public use | 3 | " | " | " |
| Total | 73 | " | " | " |

The present per capita consumption of the Croton supply in New York is about 115 gallons per capita which leads Mr. Freeman to believe that there is a probable waste of 75 gallons per capita, of which 65 gallons is needless.

Mr. Brackett, of Boston, has for many years made a most careful analysis of the metered consumption in his city, aided by investigations with the "Deacon" meter. *His estimate of the actual daily needs of a large city is as follows:

| | | | | |
|---|---|---|---|---|
| Domestic use | 30 | gals. | per | capita. |
| Business and manufacturing use | 40 | " | " | " |
| Public use | 5 | " | " | " |
| Total | 75 | " | " | " |

This allows nothing for waste, which he believes will run from 15 gallons to 100 gallons per capita, according to the use of meters and thoroughness of waste restriction in mains and house fixtures. The present per capita consumption of Chicago is 164 gallons daily, and of this not over 75 gallons are probably required for the most liberal use.

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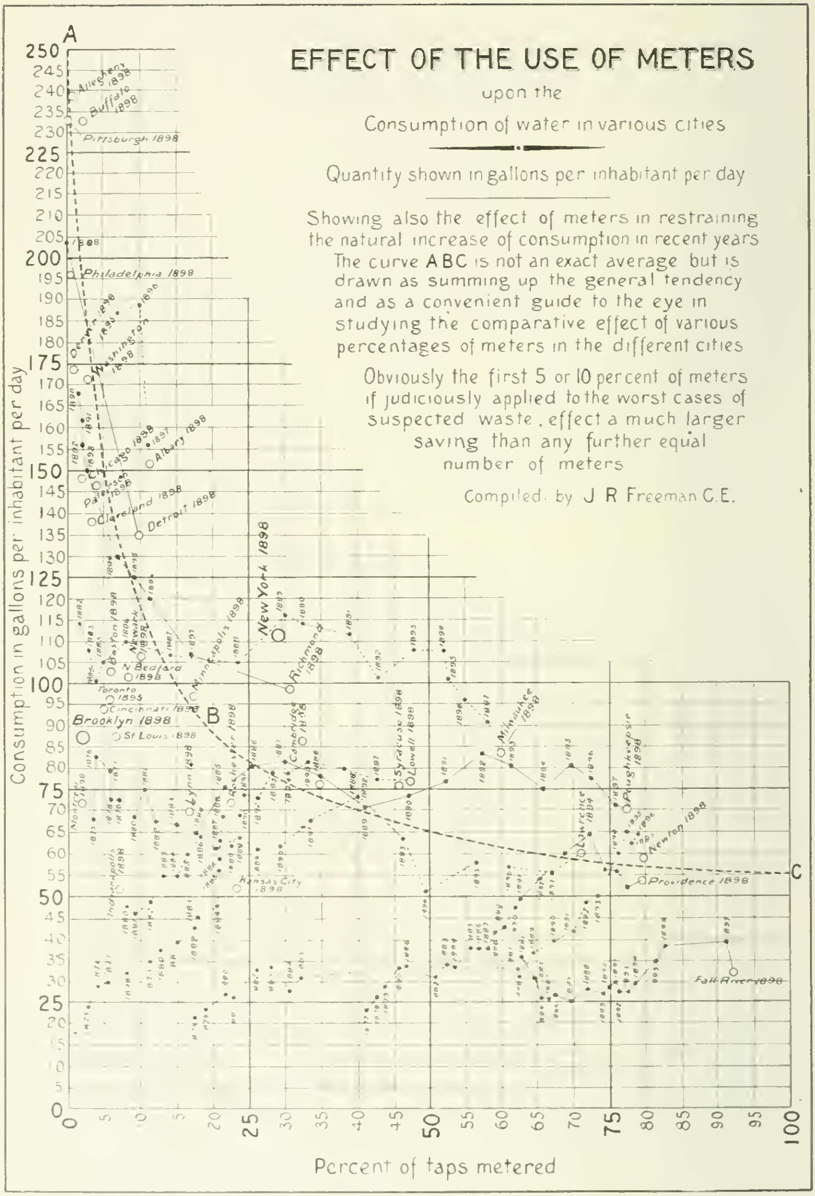
*For description and illustration of the Deacon meter the reader is referred to Trans. Am. Soc. C. E., XXXIV., 185-1895.



EFFECT OF THE USE OF METERS
upon the
Consumption of water in various cities

Quantity shown in gallons per inhabitant per day

Showing also the effect of meters in restraining the natural increase of consumption in recent years. The curve ABC is not an exact average but is drawn as summing up the general tendency and as a convenient guide to the eye in studying the comparative effect of various percentages of meters in the different cities.

Obviously the first 5 or 10 per cent of meters if judiciously applied to the worst cases of suspected waste, effect a much larger saving than any further equal number of meters.

Compiled by J R Freeman C.E.

In order to form some idea of the manufacturing use of water in Chicago, I have, through the courtesy of Mr. H. O. Nourse, Chief of the Water Bureau, secured the following approximate data. The 6,700 meters now in use are mainly on large consumers, and record a total of about 45,000,000 gallons daily, or 22 gallons per capita, which must represent a large part of the total manufacturing use. Chicago is the largest railroad center in the world, and yet the meter books show that the 15 largest roads combined use only 3½ gallons per capita. The great stock yard interests pay by meter for only about 5 gallons per capita. Thus we see that our allowance of 40 gallons may cover a very large use of water for business purposes.

An examination of the hourly records of pumpage in the various cities should convince any one of the existence of waste. The notable feature of such records is that the apparent consumption is always high, even during the dead of night. Finally, we may safely assume 100 gallons per capita to cover all legitimate use, and incurable waste, with still some allowance for a natural increase in the per capita use due to the growth of business.

We may now judge of the waste in various cities by a comparison of the per capita consumption. In reviewing such statistics we find that the relative use of meters causes a wide variation in the apparent wastefulness of cities. A diagram herewith shows a most interesting compilation by Mr. John R. Freeman, and gives the per capita use of many cities and the per cent of taps metered in each. No better argument for the judicious use of meters could be found. The effect of placing a comparatively few meters on the largest or most wasteful classes of consumers is plainly shown to give the best results for the money invested.

The most complete compilation of statistics showing the effect of the introduction of meters on water consumption in the larger cities of the United States was prepared by Mr. George I. Bailey, Superintendent of the Albany water works. He finds the average per capita consumption in 134 cities to be 137 gallons, and the effect of placing water meters is given in the following table:

| Taps Metered | Daily per capita gallons. |
|---|---|
| Less than 10 per cent | 153 gallons. |
| 10 to 25 per cent | 110 " |
| 25 to 50 per cent | 104 " |
| More than 50 per cent | 62 " |

It should be noted that those cities having the largest percentage of taps metered and the smallest consumption are the cities of moderate size. Here undoubtedly the demands are not as great as in the largest cities, where as a rule less than 10 per cent of the taps are yet metered. It does not necessarily follow that even the universal meter system would reduce the consumption of our largest cities to anything like 62 gallons. The meter system would need to be supplemented by waste restriction in the street and beyond the meters.

The chief sources of waste are as follows:

1. Defective plumbing in houses.
2. Willful waste, such as allowing water to run to prevent freezing, extravagant use of hose, etc.
3. Leaks beyond the consumer's premises in mains and services.
4. Slip of pumps, and station use.

1. Defective plumbing is a well known source of waste. The ordinary water meter is the best possible means for standing guard over it. It makes each householder his own inspector. My experience confirms the common testimony that the automatic float valve is the greatest cause of waste in the house.

2. Willful waste undoubtedly exists. Many persons will let a stream of water run rather than pay a plumber to make repairs. The loss due to opening faucets in freezing weather has been estimated by Mr. Brackett in Boston, to amount to 6 gallons per capita for the whole year. An ordinary faucet on the first floor of Chicago houses will run 6,000 to 7,000 gallons in 24 hours, an amount few people realize.

3. Leaks beyond the reach of the house meter are larger than is commonly supposed. Mr. J. J. R. Croes, C. E., in his recent report on the New York water supply, estimates that of all the waste in that city, 80 per cent is in the streets or old taps and service pipes, while only 20 per cent is in the houses. This may be an extreme view, but we do know that in a large number of cities having practically every tap metered, there is a discrepancy of from 30 to 50 per cent between the total pumpage and the total meter registration. This great loss still remains after allowing for all unmetered public uses, fires, and even for slip of pumps. The inevitable conclusion is, that water is leaking from the mains and services. The city of Yonkers, N. Y., is an example. There the discrepancy was 38.7 per cent of the pumpage, and it was suggested that a single stream of about $\frac{1}{32}$ inch diameter to each of the 3,500 taps would discharge the whole amount lost, or 1,000,000 gallons daily. In the 1,900 miles of water mains in Chicago, no one knows how many streams, from the size of a pin hole up, may be flowing into the sandy soil or neighboring sewers without ever showing on the surface. The aggregate of these small streams is enormous, but the underground leaks are not always small. There are many instances on record of broken mains discharging hun-

dreds of thousands of gallons daily into a convenient sewer, sometimes for years, before discovery.

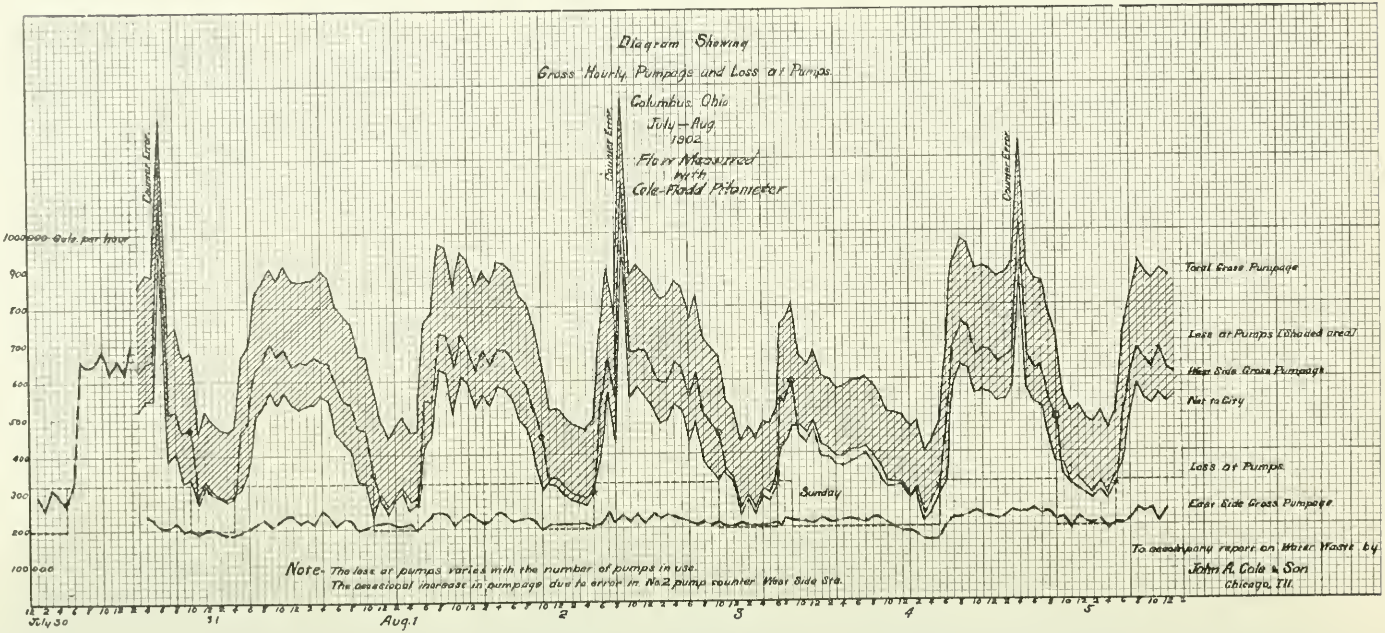
In an entirely new system, ranging in size from 4-inch to 16-inch cast-iron pipe, under 50 lbs. pressure, and before any service pipes were attached, a test reported by Mr. H. F. Dunham, C. E., shows a leakage of one gallon per minute per mile of main. A similar test made for Mr. John A. Cole, C. E., with 8 miles of smaller pipe and heavier pressure, shows a leakage of about 3.3 gallons per minute per mile. Thus showing that well-laid mains may be practically tight.

The large loss of water unaccounted for by total meter registration can hardly be caused by error in the meters themselves. In 1897, Mr. John A. Cole, C. E., president of the Des Moines Water Co., had careful tests made of 1,064 meters which had been in use in that city from 1 to 15 years. Meters suspected of slip were largely chosen. The results showed an average slip of only 1½ per cent for all the meters.

4. Slip of pumps, and station use.

All of the reported pumpage does not reach the meters. This is because of what is known as "slip" and "station use" at the pumps. It is customary to make only a very small correction for this loss, and in fact the statistics of most cities are based upon the full amount of water displaced by the pump plungers, the almost universal method being to multiply the recorded strokes of each engine by the number of gallons displaced by its plungers per stroke. The chief merit of this method lies in its simplicity. That it is liable to gross error I have found on several occasions when the actual discharge from a pump has been measured and compared with the counter record. In this way I have found a discrepancy of 25 to 40 per cent, and even more in several pumping engines. This loss should always be determined and deducted from the reported supply to the city. Slip at the pumps is not only misleading, but requires the same pump capacity, steam and fuel to pump it as though the full plunger displacement was discharged into the mains. The accompanying diagram of hourly pumpage at Columbus, Ohio, shows the slip as measured by the pitometer.

Slip or leakage is developed by wear of the plunger and valves which permits the water to "slip" by, simply churning back and forth, doing no good, but absorbing power and valuable pumping capacity, which is worse. This loss is more likely to become serious with what is known as the horizontal inside packed type of plunger, and especially when no fibrous packing is used. The presence of sand or grit in the water will quickly cause wear between plunger and ring, valve and seat, until in a few months the loss



Record of Pumpage at Columbus, O., showing nominal and net amounts and wastage.

may be enormous, as I have had occasion to know. I have measured a 29-inch horizontal plunger which was actually ¼-inch smaller in vertical diameter than its ring. The calculated discharge through such an opening as this, under a head of 170 feet, is about 4,500 gallons per minute, or nearly 65 per cent of the full capacity of the pump. The station use may be excessive, and especially for condensing purposes.

Enough has been said to show the existence and extent of water waste and we will now look for the remedy. The first step in water waste prevention is to locate the waste, and fortunately the location of waste is a perfectly simple and rational undertaking.

It is first necessary to put meters on all business houses and large users so far as possible. Next, the city is divided into large districts, closing all the main gates but one, placing a suitable waste meter on the inlet to the district, and keeping a record of all the water which goes in. The total used taken in connection with district population and the amount registered by the meters will give a good idea of the wastefulness of the section taken as a whole, the rate of night use being most significant. In case the district shows a reasonable rate of use, it may be left as it is, thereby saving the expense and trouble of a house to house inspection according to the old methods.

If, on the other hand, an excessive per capita use is indicated the next step is to localize the consumption, by streets, using the water meter to record the flow as the street valves are closed one after another. In this way the district may be analyzed until the waste meter has indicated the particular section of the district which is wasting the water. All streets do not use water at the same rate per tap, as is shown by the last columns of the accompanying waste survey tables, and for this reason it is easier to localize an unusual flow. The tabulated results show the variation in night rate of consumption by streets. When the waste has been localized within a few streets this smaller but wasteful section is inclosed by itself and is supplied through its own waste meter. The same analysis by closing street valves is continued until the greatest waste is narrowed within the limits of a few blocks. Then, if necessary, the curb cocks are closed one after another at night, the waste meter at the same time recording the rate of flow each minute, so that when a house is reached having a leaky service pipe or fixtures, the meter on the main will, on closing the curb cock, record the rate of waste. In this way a record showing the state of every house on the street is obtained and the waste is located without making unnecessary house to house inspections. The waste meter record not only locates waste on certain premises, but measures it exactly, so that the work of repair to fixtures or service pipes may proceed intelligently.

This is briefly the Deacon meter system which has been much used in England. In this country it was used by Mr. Dexter Brackett in Boston twenty years ago with success. Mr. Brackett's results with the Deacon system in Boston were most valuable. In a district with a population of 21,000 the consumption was reduced from 58.5 to 37.7 gallons per capita, a saving of 35.5 per cent.

Every large city should organize a department for the systematic detection of waste according to some such plan as has been outlined. The work calls for the intelligent and skilled supervision of an engineer and must be persistently followed up for years, if need be, to secure the final results. The time required to traverse a square mile in this way will depend on the number of waste meters and men employed at one time. Several districts could be inspected under this system at the same time under the direction of a competent head. Experience has amply proved the value of this work. Its results are felt as soon as it begins, and the cost should be repaid many times over from the savings.

The increased net income which would in a few years be possible by checking the abnormal rate of expenditure of public money for new tunnels, pumps and mains, will mean millions of dollars to the taxpayers, and will provide for the cost of purification works, which are sooner or later to be demanded in every large city. Waste prevention and purification are the order of the day. They must go hand in hand.

The well-known *Venturi meter is also adapted to this use, but it is open to the same objection as the Deacon meter in that it requires to be set in place permanently by cutting the main.

About six years ago I perfected a form of Pitot tube for use as a waste meter in an investigation at Terre Haute, Ind. The instrument proved to be cheap, accurate and efficient, and has since been used on a number of important tests. A brief description of the "Pitometer," as it is called, may be of interest.

This instrument is primarily a rate meter, depending as it does upon the velocity of the water within the main. It does not directly indicate the total discharge in cubic feet in a given time, as with ordinary meters. This elimination of the time element is necessary in a waste meter, for by the change in rate we are able to study the effect of closing valves and service cocks in such an investigation as I have just described. The illustration gives a general idea of the complete instrument with its photo recorder.

Two brass tubes bent at their lower ends, with carefully formed orifices of 1/8-inch internal diameter, are held in a suitable cap which screws upon a standard 1-inch corporation cock through which

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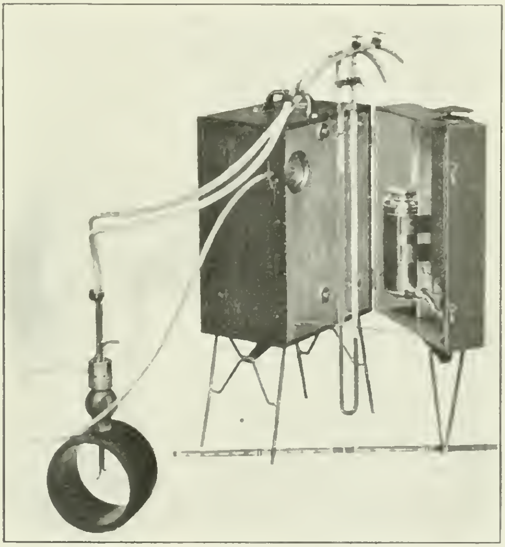
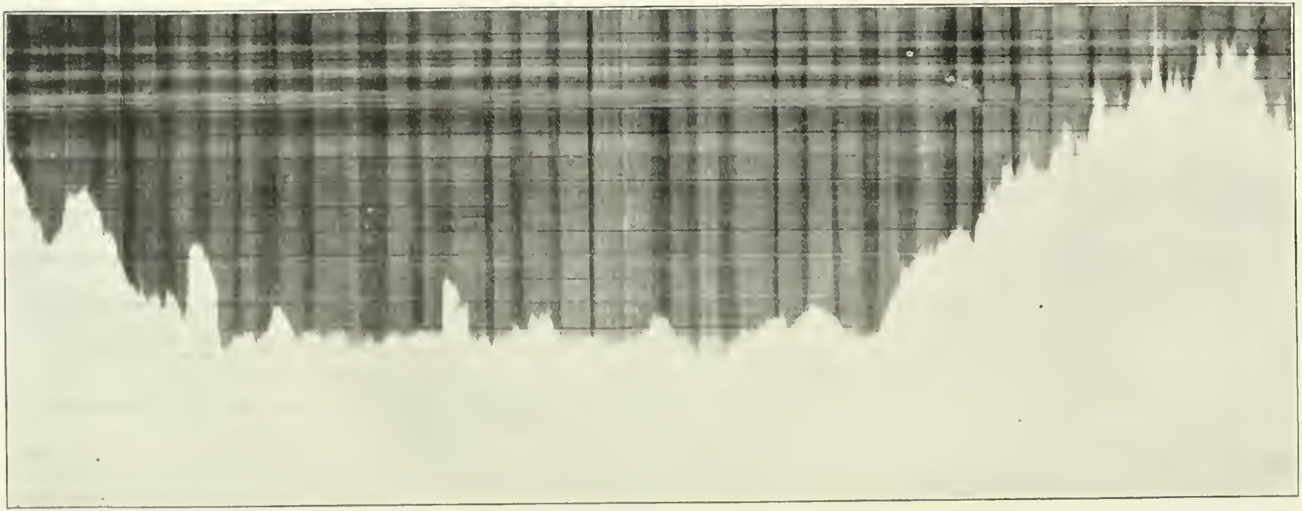
*For description and illustration of the Venturi meter the reader is referred to Trans. Am. Soc. C. E., XVII., 228-1887.

the tubes may be readily introduced into any main and as easily withdrawn.

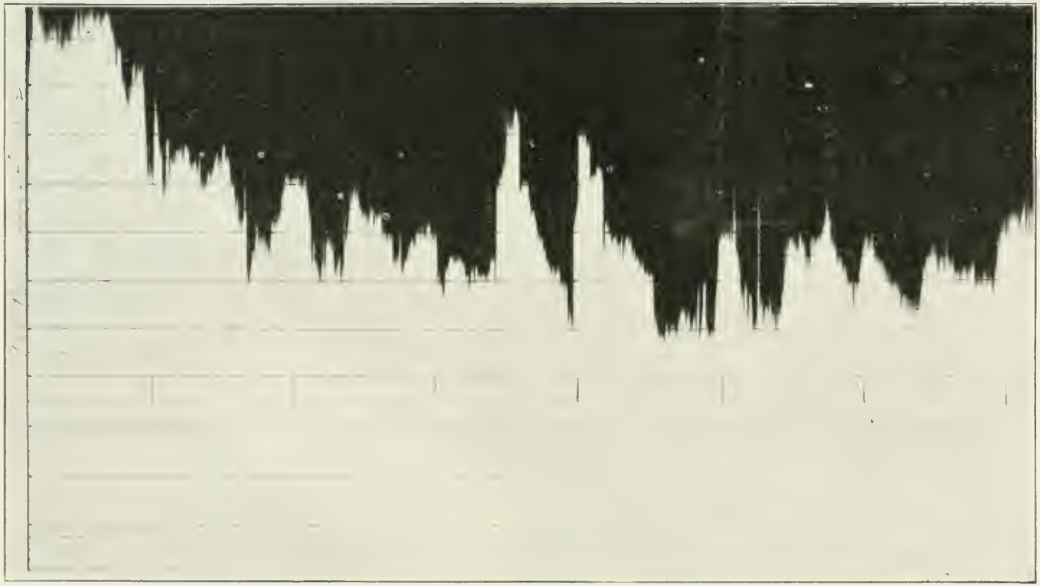
Heavy cloth-insertion rubber tubing connects the orifice tubes with a long glass manometer or U-tube and blow-off cocks are provided to remove air from the instrument. The U-tube is half filled with a mixture of carbon-tetrachloride and gasoline having a specific gravity of 1.25, and when in use the water from the pipe fills all the space in the U-tube and connections. The orifices are set to receive the maximum velocity within the main, which is usually near the center, and is readily indicated by the deflection in the manometer. This deflection, by virtue of the differential action of the water and the slightly heavier and insoluble liquid, is just four times that due to the actual difference of water head on the orifices produced by the flowing stream. The current impinges directly on one orifice, but the other is turned down stream and gives something less than the static head within the main, thus magnifying the difference of pressure produced. This difference is then multiplied in the U-tube, the result being that a low velocity within the pipe produces a readable deflection. Without this effect the Pitot tube would hardly indicate a velocity less than one foot per second, while the pitometer may be depended on, if carefully used, to measure velocities as low as 4 inches per second. At the ordinary velocities the U-tube deflections may run up to 24 inches and need not be read with any great nicety. The photo-recorder consists of a box



The Pitometer.



The Cole-Flad Pitometer on a 20-inch main. Nine-hour record reduced about half size.
Photo-Record of the consumption in a purely residence district of Columbus, O. Population of district, 46,000. The minimum recorded consumption at night per capita = 1.6 gals. per hour. Record runs from 9 p. m. to 6 a. m.



Cole-Flad Pitometer on a 16-inch main. A seven-hour record reduced about one-half. Note the sharp definition of flow which perfectly adapts the Pitometer to waste detection. Above irregular flow due to railroad use. This record began at 9:06 p. m. and continued until about 4 a. m. About seven hours is represented.

in which a drum carrying Velox paper revolves before a fine vertical slit just in front of which is locked one leg of the U-tube, in such a position that the rays of light from an oil lamp will be partly intercepted on their way through the colored liquid in the lower half of the manometer. As the liquid rises and falls with the velocity in the pipe it will record a line or band of shade on the velox paper whose ordinates vary according to the well known formula:

$$V = c\sqrt{2gh}$$

in which "h" is one-quarter of the U-tube deflection in feet or half of the recorded ordinate on the paper. A 12-hour photographic record is 18 inches long and 10 inches high. Autographic horizontal lines are formed by notches in the drum slit, spaced so as to correct for the angularity of the light and enable the deflection to be readily taken from the diagram at any point.

The accuracy of the pitometer has been established by many weir tests and by calibration in open channels where the absolute velocities indicated by the instrument were compared with float measurements.

The calibration constant "c" of the orifices has thus been experimentally determined to be .80 in our formulas.

We have then

$$V = .8\sqrt{\frac{2gd}{4}} = 3.212\sqrt{d}$$

in which d is the U-tube deflection in feet. The actual velocity of the water is indicated in this way wherever the orifices may be placed within a pipe, and by completely traversing a given pipe section on one or two diameters we may easily complete the ratio of mean to maximum velocity at some one rate of flow. This ratio once determined for a given pipe holds good at all velocities. We may then set our orifices permanently to give the maximum or center velocity within the pipe, reading off the mean velocity and the discharge from a table constructed for the particular size of pipe and velocity rates. This method leaves nothing uncertain, and after computing the traverses of many pipes varying in diameter from 4 inches to 72 inches and with different conditions as to interior roughness, I am satisfied that the method is a reliable one. The mean velocity computed from a traverse of a pipe with the pitometer has been checked by actual weir or pump measurement of the flow in pipes with close agreement. I have reason to believe that the flow may be determined by the pitometer method within 2 or 3 per cent of the truth in fairly clean pipes when the velocity exceeds one or two feet per second. Velocities as low as 4 inches per second may be measured, but with less precision.

## DISCUSSION.

*Mr. John Ericson*—Did I understand you to say, Mr. Cole, that the loss by waste inside of the curb is about one-fifth of the total, and that four-fifths would be assumed to be lost outside the curb?

*Mr. Cole*—That is said to be the opinion of Mr. J. J. R. Croes, of New York.

*Mr. Ericson*—Did he make extensive investigations in regard to that?

*Mr. Cole*—He is considered an expert in water waste, and I think he has given a good deal of attention to the matter.

*Mr. Ericson*—I did not know that he had estimated the loss inside the curb at one-fifth.

*Mr. Cole*—The statement has been quoted in a number of technical papers which I have found, and it seems to be everywhere accepted.

*Mr. Ericson*—I do not know whether it is true or not, but I have heard that the Deacon system which has been in use in Boston for a long time has been lately abandoned on account of the excessive cost.

*Mr. Cole*—Mr. John R. Freeman's New York report contains a somewhat similar statement, and I have taken pains to inquire in Boston in regard to the Deacon meter department. I am satisfied that the efficiency of the system suffered when Mr. Brackett left the city's employ and took up the work of the Metropolitan Water Board. Under Mr. Brackett's direction the Deacon meters proved to be of great value to the city, and a high standard of efficiency was maintained.

Of late years the organization of the department has changed and the element of personal responsibility and interest has largely disappeared from the corps.

*Mr. Ericson*—How does the cost compare, using the Deacon system and tubes?

*Mr. Cole*—The pitometer serves exactly the same purpose and was designed to save us money in just such an investigation. We had not the funds for the purchase of expensive meters, and found that one pitometer would do the work of several Deacon meters and save a great deal in the cost of apparatus and installation.

*Mr. Ericson*—About what is the cost of the Deacon meter—for say 6-inch pipe?

*Mr. Cole*—It has been given at about $600. I understand that to be about the cost of a 6-inch meter set in place.

*Mr. Ericson*—Of course the cost increases according to the size.

*Mr. Cole*—Yes, the cost increases with the size.

*Mr. Ericson*—About how many Deacon meters were used in Boston at any one time?

*Mr. Cole*—About eighty-three.

*Mr. Ericson*—Would it be necessary, assuming that the pitometer system could be adopted instead of using Deacon meters, to have that number of instruments?

*Mr. Cole*—No. There would be no need of so many pitometers. Only a few would be required, and they would be carried from place to place as the work progressed.

*Mr. Ericson*—The work of course would principally have to be done at night.

*Mr. Cole*—Not entirely, the curb cock inspection could only be made at night, but the preliminary investigations in a city by large districts would not call for much night work.

*Mr. Ericson*—Is the flow of the water flowing into a certain district to be determined at the same time as the inspection of the taps, in order to determine the waste?

*Mr. Cole*—The idea that I tried to give was that the work began with the preliminary survey which extended over large areas, and that the areas were gradually made smaller and smaller, until finally the most wasteful sections of the district were set apart and inspected in the detailed manner as described, by closing curb cocks at night.

*Mr. Ericson*—Take our complicated system here in Chicago, would you have to shut off all mains leading into one district except one, two or three?

*Mr. Cole*—Probably two mains with a pitometer would supply the average district, with a third main held in reserve in case of fire.

*Mr. Ericson*—Have you given any thought to the possible time it would take to make a preliminary survey of the most important districts of the city of Chicago?

*Mr. Cole*—I do not think I could give you an estimate of the cost at present. Local conditions vary so much that I should prefer to base an estimate on a short preliminary survey.

*President Finley*—I understood Mr. Cole to say that under the efficient management of Mr. Ericson they had $1.000,000 receipts from our water tax. Why should we be restricted in the use of water? We are near one of the largest bodies of fresh water in the world, and if Mr. Ericson is earning $1,000,000 a year for the city, I do not see any need in restricting the use of water.

*Mr. Ericson*—I do not think there is any intention, Mr. President to restrict the use of water, but I do not see of what use the water is to the citizens of Chicago that runs into the sewers without being used at all, and that which soaks into the ground. It has been stated by health authorities that they consider waste necessary for the cleansing of sewers, but if they will consider the whole pumpage of the city of Chicago distributed over the area of the city, they will find it equivalent to a rainfall of $\frac{1}{192}$-inch an hour or ⅛-inch per day. I do not think such a rainfall would accomplish much flushing of the sewers.

*Mr. Milligan*—I think Mr. Cole's valuable paper has shown very clearly that the normal usage might be considered to be 70 gallons per consumer as against the amount pumped, 165 gallons. He has also shown very clearly that meters are necessary in such cities as Fall River. But even there where a complete system of meterage may be considered to have been installed, there is still a waste of between 30 and 60 gallons per capita, which really benefits no one—as I have followed his paper tonight. If I am not correct in that deduction I would like to have Mr. Cole so advise me.

Applied to Chicago, I think Mr. Ericson is right in saying that it benefits no one, and it certainly costs the average citizen of Chicago a certain amount to pump each gallon of water passed, and any method that will detect the ensuing waste, and locate it to a certain section of the city, would enable a superintendent or inspector to correct it by proper inspection of the pipes and sewer system of that particular section of the city.

If I am correct in these deductions from Mr. Cole's paper I would be very glad to know it; if not, I would like to have Mr. Cole correct me.

*Mr. L. E. Cooley*—I would like to ask Mr. Ericson or Mr. Cole if they have ever made an estimate in regard to the cost of metering the domestic supply of Chicago to the user?

*Mr. Ericson*—I have been asked by the City Council to make a report on that very subject. I have not close enough figures to give here tonight, but I can say this much, that if we take into consideration the tendency to an increased consumption of water per capita, I would think that in ten years from now there would be 200 gallons per capita; I do not think that would be assuming too much. Looking at the increase in population, I should think that ten years from now we may have pretty nearly 3,000,000 people. At that rate we would have to have a pumpage in the city of Chicago, ten years from now, of, if not double, pretty nearly double, the present capacity. I look back ten years and see what we have spent in the construction of pumps, pumping stations, etc., not to mention the pipe system, which has also to carry this enormous flow, whereby, of course, the head is greatly reduced, and I find it to be about $8,000,000. It is fair to assume that we would not spend any less in the next ten years if we want to keep up with the demand for water, of which, as has been previously stated, such a great percentage is wasted and of no use to any one. Taking that into consideration, I say it will amply pay to meter the city, even in this city where the question has been taken up so late,—but better late than never.

I had a letter from the City Engineer of the city of Milwaukee (this morning, I believe) in reply to one I wrote him, asking a few questions in regard to meters etc., and he says that they now have in Milwaukee 36,000 meters, and if I remember correctly it was only two or three years ago when they had but 15,000 meters. They are not pumping any more water today than they did ten years ago. If you will recall to mind that curve which Mr. Cole called our attention to on the diagram, prepared by Mr. J. R. Freeman, you will see that it is not necessary to go to the extreme of metering all the taps in the city.

A gentleman remarked to me today that it would be exceedingly unfair to charge a poor property holder $15.00 or $16.00 for a meter, when his water tax does not amount to more than $2.00 or $3.00; in other words, to charge him for his meter enough money to pay his water tax several years. Of course we do not want to inflict any hardship, and it is not necessary, as this very diagram, referred to above, illustrates so well. Besides, I believe the city should pay for the meters.

There has been much said about this meter question as a general proposition, and it has been occupying my mind for a considerable time. Every commodity is sold by weights, measures, etc. Certainly water is as free as the air, but we have to pump it, and we have to expend money to bring it where we want it, and I say, as a general proposition, that in order to make it fair to the consumer as well as the seller, it should be sold by measure, because, as it is, under present conditions, it is like other taxation—the poor man has to pay *too much* and the rich man has to pay *too little.*

*Mr. Cooley*—I agree most fully with the last speaker in regard to the desirability of metering water. I would go a little further and meter it to the poor man as well as the rich. I do not think $15.00 for a meter attached to each house should necessarily be prohibitive or a hardship. I think there should be a tax or deposit for a water meter just the same as there is for a gas meter. I have been very much interested in the discussion and especially in the paper, and in the idea of street waste. It has been stated that in the use of gas in the city of Chicago there is a loss of 25 per cent of all the gas produced, between the gas meter and house meter. It has also been stated that such towns as Evanston lose over 50 per cent. I quite sympathize with any improvement that can be made in regard to measuring the water, and am surprised to know that it is not done in connection with our pumps and street pipes here in Chicago. It should be measured to the users the same as gas and electric light, and let the poor man benefit by any economy in its use.

*Mr. C. B. Burdick*—About one year ago, the firm with which I am connected, and with which Mr. Cole is connected, had occasion to investigate the use and waste of water in the city of Oskaloosa, Iowa. Mr. Cole has referred to the survey of that place in his paper. A general summary of the conclusions arrived at may be of interest in connection with this paper.

After making investigations of the uses at the pumping station and in the filter plant, and of the leakages in the mains and service pipes through various means, we came to the conclusion that when the use of water in Oskaloosa was approximately a million gallons in twenty-four hours, the use and waste was distributed approximately as follows:

359,000 gallons per day, water drawn from the taps.
50,000 gallons per day, water used in washing filters.
350,000 gallons per day, wasted in slip in the pumps.
162,000 gallons per day, leakage on the premises of the consumers.
41,000 gallons per day, leakage in mains and services in city streets.
38,000 gallons per day, leakage in mains from the pump works to the city.

There are about seventeen miles of street mains altogether. That would make a total of about 409,000 gallons of water which was actually drawn from the taps, and about 591,000 gallons served no useful purpose; total, one million gallons.

Out of the 359,000 gallons drawn from the taps, 140,000 were used by one railroad, 24,000 were used by another railroad, and four other large consumers used enough to make a total of 247,000 gallons. Subtracting the use of four of the largest consumers—247,000 gallons per day—from 359,000 gallons per day, leaves 112,000 gallons per day to supply the remaining 675 taps, which makes an average of 166 gallons per tap per day.

*Mr. Ericson*—I wish to ask just where the majority of this loss occurs. Is it lost in the mains, service pipes or wasteful use of the water?

*Mr. Burdick*—We made no attempt in that survey to detect the excessive use of the water. That amounts to something in certain seasons of the year—especially extreme warm and extreme cold weather. The large waste at Oskaloosa was a waste constantly going on, and consisted largely in slip in the pumps and leakages from the mains and service pipes.

*President Finley*—Was the loss in the pumps greater than the leakage in the mains?

*Mr. Burdick*—The loss in the pumps should be small. In this particular case we found it very large. It was an unusual case. 40 per cent of the entire pumpage was lost in the pumps and never left the pumps at all. The loss in the mains was about 79,000 gallons per day out of a total pumpage of 1,000,000 gallons.

*President Finley*—What was the loss in the service pipes?

*Mr. Burdick*—About 162,000 gallons.

*President Finley*—Where are the meters usually placed in the cities that are using meters?

*Mr. Ericson*—In some cities they place them outside the curb and in some places inside in the basements, like gas meters. I may perhaps be able to answer Mr. Finley's question in regard to where water is most largely wasted, and will mention a certain case that will give some idea. In discussing a paper written something over a year ago by Mr. Spengler I called attention to the statement of an engineer in the *Water and Gas Review*. He lives in a "well-to-do" house and had a family of about four or five. He had a meter installed in his house and thought that he was using a good deal of water—in fact, too much. For several days in succession he read the meter just after closing all the faucets at night and before any water was used in the morning, and found that during those hours when he knew they had used no water at all, a considerable amount of water had passed through the meter. He then sent for a plumber and the plumber found that some of the faucets were dripping, and that along the back of the water closet there was a small stream running, due to a leaky valve, a case which often occurs. These leaks were stopped and he continued to take his meter readings. After the plumber had been there and fixed the fittings the meter registered about one-third, or a little more, of what it registered before. In other words, there had been, on account of those leaky fixtures, about 50 or 60 per cent of all the water he used in the house wasted.

*Mr. McArdle*—Some two years ago, in conversation with the president of the village of Wilmette, he complained to me of the enormous waste of water there. The water was received through meters from the city of Evanston and meters were installed at each house, and the amount of water used through the main water pipe was checked up, showing that 25 per cent of the the total amount received was metered to the consumers, thus indicating a loss of 75 per cent of the total amount charged against the village of Wilmette.

*President Finley*—Can you trust its veracity any further than you can the gas meter?

*Mr. Burdick*—Some years ago we had occasion to make a general test of the meters of the Des Moines Water Company, and the result of our tests there was to strengthen our minds in the belief that the water meter is a very reliable instrument. As Mr. Cole has stated, the average slip of about 1,300 meters was only 1½ per cent; that is, they registered on an average about 98½ per cent of the water that went through. That, I think, is a very good showing for the water meter.

*Mr. Cooley*—What was the make of the meter?

*Mr. Burdick*—Nearly all the different makes that are manufactured are used there—six or eight different makes. The average meter was in favor of the consumer. We found some meters which tested 100 per cent, but none were more than 1½ per cent high, and a great many registered low. When a meter is in first class order it registers about 100 per cent. As a meter becomes worn it tends to register a less quantity of water, especially if only a portion of the capacity of the meter is used, so that wear is always favorable to the consumer.

# CLX.

## FIRE EXTINGUISHMENT IN CHICAGO.

## THE FIRE DEPARTMENT.

By William H. Musham.*

*Presented Nov. 19, 1902.*

The fire extinguishing force in the early days of Chicago consisted of a bucket company, the buildings being small and principally of wood. This answered until the city increased in size and population, then hand engines, hook and ladder trucks and hose companies were introduced. The hand engines were of different patterns, selected by the companies handling them. They were partly paid for by the corporation, but the ornamentation of each engine was paid for by the company operating it. Each engine company was entitled to eighty men, hook and ladder companies forty men, and hose companies twenty-five men, officered as follows: Foreman, first and second assistant foreman, secretary, treasurer and steward, elected annually by the members of each company, and all were volunteers.

This system continued until the buildings began to increase in size and area, when it became necessary to reorganize the department into a paid force with steam fire engines manned by nine men to each engine. The hook and ladder companies were also manned by nine men. The first steam fire engines in Chicago were of a rotary pattern, capable of discharging about 500 gallons of water per minute. They were very heavy and required four horses to draw them. They were also slow in steaming and it was necessary to place a fan in the smoke stack to give them draft. These engines being so unwieldy, were replaced by lighter engines of greater capacity known as double piston engines. The pump had a bore of five inches and a stroke of twelve inches, and was capable of discharging about 1,000 gallons of water per minute. These engines were drawn by two horses.

About the year 1874 three self-propelling engines were purchased by the city, but these were changed to horse engines on account of the high pressure of steam required to keep them ready for service, which caused the boilers to leak continually. Constant working of the pumps in connection with the propelling power also loosened the leathers in the pumps, causing a loss of power while in action at fires. Engines of this class will hardly prove successful until the pumps are disconnected from the propelling power.

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*Fire Marshal, Chicago.

Chemical engines were first introduced into the department after the great fire of 1871, and have proved to be a very valuable auxiliary. The hook and ladder trucks changed from a very light straight frame apparatus to the present aerial trucks with 90 foot ladders. The hose has also been vastly improved, changing from the heavy copper riveted leather hose to rubber, and from rubber to the light cotton hose lined with rubber.

The rapid change of buildings in Chicago is familiar to everybody, and at present we have buildings ranging from a one story frame or wooden structure to twenty-two story fire-proof buildings of steel construction.

## EXPENSES.

The following table is a comparative statement of the yearly expenses of the department, with the expense per capita of population and the number of companies maintained for each year since 1870:

| Year. | Amount Expended. | Population. | Amount Per Capita. | Number of Companies. |
|---|---|---|---|---|
| 1870 | $ 366,700.66 | 306,605 | $1.19½ | 26 |
| * 1871 | 182,023.15 | 337,000 | .51 | 28 |
| 1872 | 432,057.34 | 367,393 | 1.17½ | 35 |
| 1873 | 586,618.96 | 381,402 | 1.53 | 41 |
| 1874 | 624,795 22 | 395,408 | 1.57 | 43 |
| § 1875 | 411,245 12 | 401,535 | 1.02 | 43 |
| 1876 | 478,340.22 | 407,661 | 1.17 | 41 |
| 1877 | 507,001.12 | 422,196 | 1.20 | 42 |
| 1878 | 389,692.36 | 436,731 | .89 | 42 |
| 1879 | 420,308.82 | 469,515 | .89 | 41 |
| 1880 | 454,301.18 | 503,298 | .90 | 43 |
| 1881 | 568,760.87 | 531,996 | 1 07 | 45 |
| 1882 | 545,021.03 | 560,693 | .97 | 45 |
| 1883 | 556,551.80 | 595,339 | .93 | 45 |
| 1884 | 657 957.46 | 629,985 | 1.04 | 47 |
| 1885 | 717,639.92 | 661,923 | 1.08 | 49 |
| 1886 | 823,413.02 | 693,861 | 1.19 | 52 |
| 1887 | 826,047.74 | 748,256 | 1.10 | 57 |
| 1888 | 893,475 09 | 802,651 | 1.11 | 58 |
| † 1889 | 961,201.54 | 900,000 | 1.07 | 59 |
| 1890 | 1,278,337 41 | 1,099,133 | 1.16 | 85 |
| 1891 | 1,378,219.16 | 1,117,000 | 1.20 | 99 |
| 1892 | 1,459,754.93 | 1,197,000 | 1.22 | 102 |
| 1893 | 1,542,378.17 | 1,250,000 | 1.23 | 105 |
| 1894 | 1,500,542.62 | 1,305,000 | 1.15 | 107 |
| 1895 | 1,542,596.62 | 1,362,000 | 1.13 | 108 |
| 1896 | 1,502,912 66 | 1,427,000 | 1.05½ | 109 |
| 1897 | 1,532,780 92 | 1,485,000 | 1.03 | 111 |
| 1898 | 1,566,081.96 | 1,558,000 | 1 00½ | 112 |
| 1899 | 1 611,346.67 | 1,626,000 | 1.01 | 115 |
| 1900 | 1,678,410.09 | 1,698,575 | .98½ | 120 |
| 1901 | 1,636,984.21 | 2,082,695 | .78¾ | 121 |

* Six months. † Annexed territory not included. § Nine months ending December 31, 1875.

| Recapitulation of the Apparatus, etc., of the Department, December 31, 1901. | In Service. | In Reserve. | Total. |
|---|---|---|---|
| Fire-Boats | 4 | 1 | 5 |
| Water Towers | 2 | .... | 2 |
| Steam Fire Engines, special 1st class | 6 | .... | 6 |
| Steam Fire Engines, extra 1st class | 4 | .... | 4 |
| Steam Fire Engines, 1st class | 22 | 2 | 24 |
| Steam Fire Engines, 2d class | 39 | 7 | 46 |
| Steam Fire Engines, 3d class | 1 | 1 | 2 |
| Steam Fire Engines, 2d class, combination | 1 | ... | 1 |
| Steam Fire Engines, 3d class, combination | 14 | .. | 14 |
| Total Steam Fire Engines | 87 | 10 | 97 |
| Fire Engines, manual | 2 | 2 | 4 |
| Chemical Engines, two-horse | 3 | .... | 3 |
| Chemical Engines, one-horse | 9 | 2 | 11 |
| Chemical Engines, manual | 2 | 1 | 3 |
| Chemical Engines and Hose Carriages combined | 4 | ... | 4 |
| Chemical Engines, Trucks and Hose Carriages combined | 6 | .... | 6 |
| Total Chemical Engines | 24 | 3 | 27 |
| Hose Wagons, two-horse | 9 | 3 | 12 |
| Hose Wagons, one-horse | 44 | 2 | 46 |
| Hose Carriages, two-horse | 13 | 12 | 25 |
| Hose Carts, manual | 6 | 1 | 7 |
| Hose Carriage and Chemical combined | 4 | .... | 4 |
| Hose Carriage, Chemical and Truck combined | 5 | 1 | 6 |
| Hose Wagon and Steam Fire Engine combined | 15 | .... | 15 |
| Total Hose Wagons, Carriages and Carts | 96 | 19 | 115 |
| Hook and Ladder Trucks, Turn-Table Extension, 1st class | 5 | .... | 5 |
| Hook and Ladder Trucks, Turn-Table Extension, 2nd class | 6 | .... | 6 |
| Hook and Ladder Trucks, straight frame, 1st class | 12 | 2 | 14 |
| Hook and Ladder Trucks, straight frame, 2d class | .... | 2 | 2 |
| Hook and Ladder Trucks, Chemical and Hose Cart combined | 4 | .... | 4 |
| Hook and Ladder Trucks, manual | 3 | ... | 3 |
| Total Hook and Ladder Trucks | 30 | 4 | 34 |
| Chemical Extinguishers, large | 2 | .... | 2 |
| Chemical Extinguishers, small | 21 | ... | 21 |
| Portable Pumps | 102 | .... | 102 |
| Fire Ladders, feet | .... | ... | 9,409 |
| Pompier Ladders, 16 feet each | ... | .... | 109 |
| Siamese connections, 2-way | 88 | .. | 88 |
| Siamese connections, 3-way | 9 | .... | 9 |
| Siamese connections, 4-way | 13 | .... | 13 |
| Total Siamese connections | 110 | .... | 110 |
| Horses | .... | ... | 481 |
| Hose, Rubber, feet | .... | .... | 16,272 |
| Hose, Cotton, feet | .... | .... | 186,423 |
| Wagons, 2-horse | .... | .... | 25 |
| Wagons, 1-horse | .... | .... | 29 |

## PRESENT ORGANIZATION OF DEPARTMENT.

The present force of the department is as follows: 1 fire marshal and chief of brigade, 3 assistant fire marshals, 1 fire inspector, 17 chiefs of battalion, 1 superintendent of machinery, 1 superintendent of horses, 116 captains, 125 lieutenants, 100 engineers, 93 assistant engineers; 670 pipemen, truckmen and drivers (divided into four classes, depending on years of service); 10 pilots, 12 stokers and 7 watchmen. The above comprises the uniformed force.

In the non-uniformed force there are 1 secretary, 1 chief clerk, 1 clerk and storekeeper, 1 clerk and stenographer and 2 hostlers. In the city telegraph, under the chief of brigade, there are 1 chief operator, one chief of construction, 1 assistant chief operator, 4 operators, 8 assistant operators and 1 repairer. This gives a total force of 1,179 men. Volunteer companies at Riverdale and Norwood Park are furnished with supplies and apparatus and make reports to the department. The number of volunteers in service is 59. The uniformed force, exclusive of the staff of the Fire Marshal, operate 92 engine companies, including 1 double company and 5 fireboats, 27 hook and ladder companies, 3 hose companies, 2 water towers operated by truck companies, and 14 chemical engines operated by truck companies. The apparatus is valued $958,970, the houses at $693,300 and real estate at $368,578.

The department is governed by rules and regulations prescribed by the Fire Marshal, consistent with the ordinances of the City Council. The department since 1895, with the exception of the Chief, has been under the control of the Civil Service Commission. Examinations as to original appointment of the uniformed force are held by the Civil Service Commission under the following rules:

## FIRE DEPARTMENT.

SECTION 1. All original appointments to the uniformed force of the Fire Department, shall be made to the lowest grade in the several branches of said service, and advancement to higher grades shall be by promotion. Every applicant, in addition to the requirements specified in Rule III, must, at the time of examination, be between the ages of twenty-one and thirty-three years, not less than five feet seven inches in height (in bare feet), and his weight and circumference of chest must be in accordance with the following table; provided, however, that applicants who have had previous experience in said department, and who were separated therefrom without fault or delinquency on their part, may deduct from their actual age any time not exceeding five years, during which they have continuously served in said department.

FIRE SCHEDULE.

| Height. | Minimum Weight. | Maximum Weight. | Minimum Circumference of Chest, Quiescent. |
|---|---|---|---|
| 5 feet 7 inches. | 140 pounds. | 180 pounds. | 34 inches. |
| 5 " 8 " | 145 " | 185 " | 35 " |
| 5 " 9 " | 150 " | 190 " | 35½ " |
| 5 " 10 " | 155 " | 195 " | 36 " |
| 5 " 11 " | 160 " | 200 " | 37 " |
| 6 " | 165 " | 210 " | 37½ " |
| 6 " 1 " | 170 " | 215 " | 38 " |
| 6 " 2 " | 175 " | 225 " | 39 " |
| 6 " 3 " | 180 " | 230 " | 40 " |
| 6 " 4 " | 185 " | 235 " | 41 " |

NOTE.—A modification of the chest measurement required in this schedule may be allowed as follows:

To an applicant whose height is between 5 feet 9 inches and 6 feet, a reduction of 1 inch or any fraction thereof.

To an applicant whose height is 6 feet or over, a reduction of 1½ inches or any fraction thereof.

Provided, that in each case the applicant shall have a chest expansion of 3 inches or more.

There shall be a difference of at least two inches between forced and full inspiration.

On requisition to the Fire Marshal eligible lists will be furnished as required. The candidate is assigned to a company for a period of six months, during which time it is necessary that he show his ability to become a fireman. The candidate is thoroughly drilled and instructed by the company officers as to the use of the appliances and the rules and regulations of the department. If he proves efficient, he is accepted by the Fire Marshal on recommendation of the officer in command of the company, and becomes a regular member of the department, fourth class, subject to the rules and regulations governing the same. He serves for a period of six months in fourth class and is then promoted to third class, and then serves a year in each class until the first, the compensation depending upon the class. According to the rules of promotion, it is essential that a member serve as a truckman or pipeman for at least one year in first class. He is then eligible to take an examination for promotion. The said rules also apply for promotional examinations to captains, battalion chiefs and assistant fire marshals. Examinations for promotions are held by the Civil Service Commission with the questions on duties furnished by the Fire Marshal, due weight being given for efficiency and seniority of service. The efficiency mark is obtained from the records of the applicant as kept by the department. Eligible lists are posted from the results of these examinations, and on requisition from the Fire Marshal to fill a vacancy in any position three names of men standing highest on the list are furnished. The Fire Marshal has the power to select any one of the three.

The city is divided into seventeen battalion districts, which are formed into three divisions for inspection purposes. The inspection divisions are under the direction of the assistant fire marshals. The battalion districts are under the control of battalion chiefs who are responsible for their efficiency and discipline.

The Fire Marshal has sole and absolute control and command over all persons connected with the fire department of the city, and possesses full power and authority over its organization, government and discipline and has the custody, subject to the directions of the City Comptroller, of the engines, hose-carts, trucks, ladders, horses, telegraph lines and all other property and equipment belonging to the fire department. The Fire Marshal may prefer written charges without oath for violation of the rules and regulations or orders of the department against any member upon his knowledge, or upon written information communicated to him by any member of the department. During the pending of charges against any member of the department the Fire Marshal may suspend from duty any such member until the charges can be investigated. The Fire Marshal prepares and submits to the Comptroller each year an estimate of the whole cost and expense of providing and maintaining the fire department of the city. He prescribes limits at fires within which no person, except those who reside therein, firemen, policemen, and others admitted by an officer of the fire department shall be permitted to come. He has power to remove or wreck buildings to check the progress of a fire. He has the power to require the assistance of citizens at a fire.

The Assistant Fire Marshals are each in charge of one of the inspection divisions. They make quarterly inspections of all companies in their districts, and report upon the efficiency of the company as shown on trial tests and the condition of the horses and apparatus. The battalion marshals are each in command of a district and are responsible to their superiors for the efficiency and discipline of the companies. They must make frequent inspections in order to become familiar with their districts. Schools are maintained for the instruction of the company officers of the various battalions, and are conducted by the assistant fire marshals and battalion chiefs.

The Fire Inspector investigates all suspicious fires and acts as public prosecutor. He has the power of a Justice in compelling the attendance of witnesses at investigations.

For any transgression of the rules and regulations of the fire department any member is subject to charges, and in case of serious offenses the power of suspension is vested in commanding officers.

Such suspension is effected by a demand made for the badge of office and an order to discontinue to wear uniform. If the interests of the department would not suffer by his remaining on duty, a written charge is made, stating what rule was violated, the time and place, and the witnesses by whom the facts may be proven. A copy of the charge is served the accused. The accused appears before a trial board, consisting of the Fire Marshal and any two assistant marshals, together with the secretary of the Civil Service Commission. The officer and witnesses being present, the charge is read by the department secretary and the accused allowed to make answer of guilty or innocent, after which the officer states his case. If the plea is "not guilty," the officer is asked to make a statement, and the accused and witnesses testify. When sufficient evidence is obtained a determination of the case is arrived at. The punishments which may be inflicted are reprimands, forfeiture of pay, suspension from duty or dismissal, according to the gravity of the offense. The findings of the board are subject to revision by the Civil Service Commission and are made known to the department through the medium of a general order, issued by the Fire Marshal.

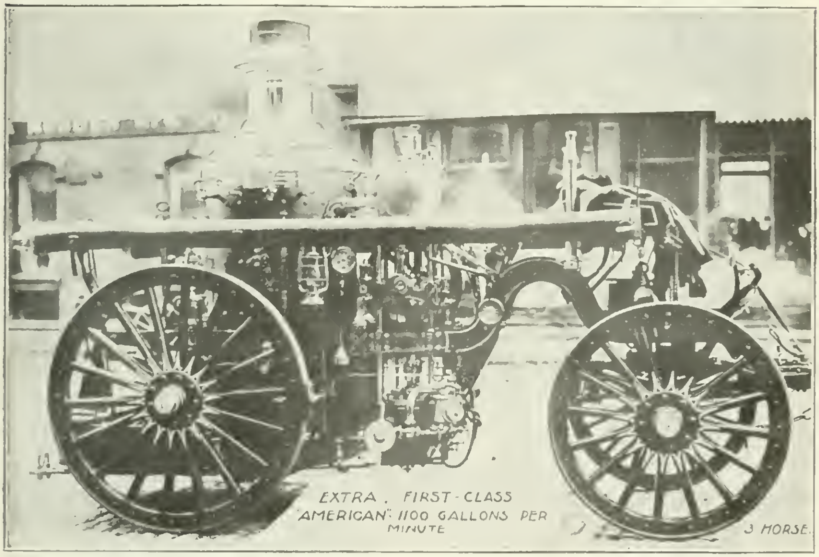
In the case of fire, the first captain arriving is in command and remains in command until relieved by a superior. Also the first battalion chief arriving is in command, all others being subordinate to him. The assistant marshals take command in order of their rank. The first company at a fire goes to work immediately, all others must report to the commanding officer.

The company officers must inspect their districts and be familiar with the conditions of the buildings, the location of hydrants and cisterns and the condition of the streets.

## HOUSES, APPARATUS, ETC.

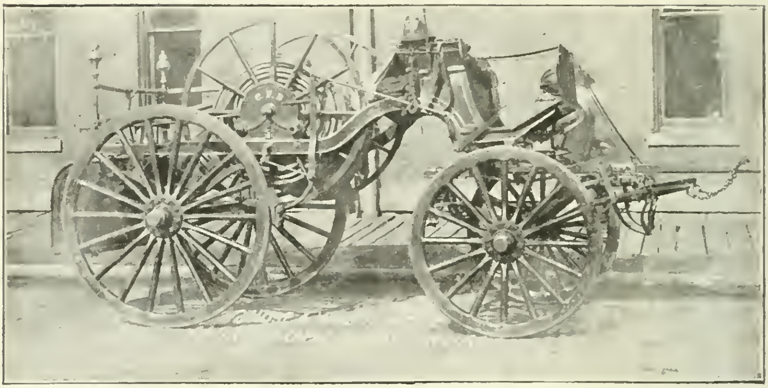
The houses are generally brick, two story and basement, and in outlying districts have usually a watch tower. The houses for the truck companies have also a tower for pompier practice. The basement contains the heating apparatus for the houses, and in engine houses an additional heater is used to keep at least twenty pounds of steam pressure on the engine at all times. The first floor is occupied by the apparatus, horses, and the fire alarm system; the second floor, for sleeping quarters for the men and separate rooms for the officers, and has communication with the first floor by means of sliding poles, in addition to the stairs. In engine houses the hose-cart is placed in front of the engine and proceeds first to the fire, while in truck houses the chemical engine proceeds first to a fire. Hose-towers in engine houses are used for drying hose by hanging it full length, if possible. The hose must be removed as soon as it is dry to prevent stretching. The watch towers are for the purpose of detecting fires in their incipiency, the watches being held during the night.

In the business districts a box alarm is responded to by at least five engine companies, two truck companies, two chemical companies, and a fire boat and hose tender if a fire is along the river. At a serious fire in the business districts 35 engine companies can be concentrated in about twenty minutes. The territory left unprotected by these calls is provided for by the transfer of engine and truck companies from other districts, where they may be spared, by orders of a battalion chief in command at fire alarm headquarters.



His duty also while in attendance at such quarters is to make provision for supplying additional companies that might be called. The largest number of companies ever at a fire in Chicago was at the lumber yard fire in 1894, where there were 51 engine companies.

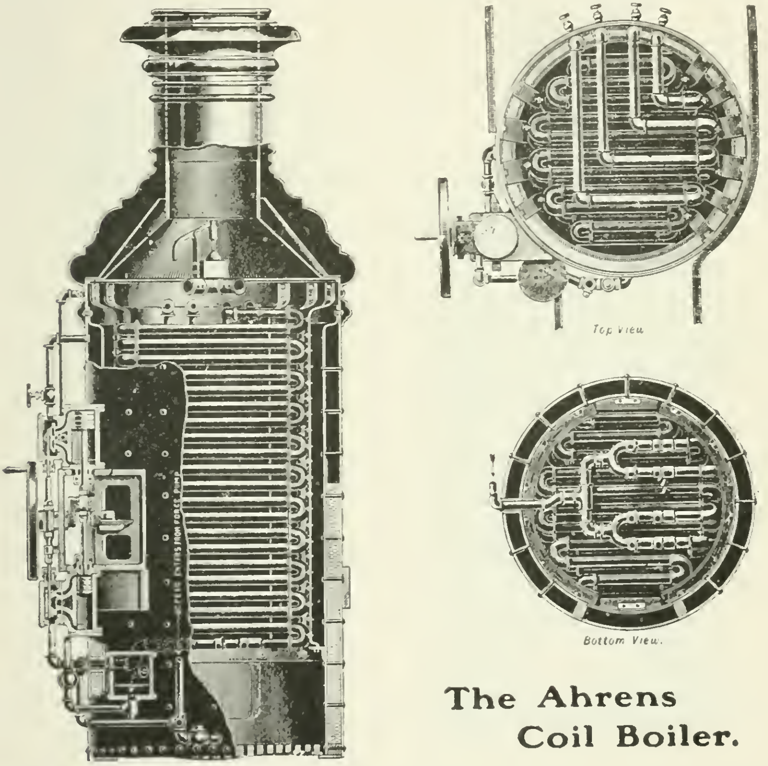
An engine company in the business districts consists of a hose wagon and a steam fire engine, manned by a captain, lieutenant, engineer, assistant engineer, six pipemen and two drivers. The hose wagon is a four wheel platform spring wagon with box space for 800 feet of 2½-inch cotton hose. On a seat over the hose are placed a rope jumping net, a siamese connection with hose and pipe attached, axes and pike poles, 200 feet of ⅝-inch rope, street pipes, two shut-off pipes, hose straps, spanners, reducers for hydrants, a



portable pump and a bucket. This apparatus is drawn by one horse. The rope jumping net is used for life saving purposes. The siamese connection is for concentrating two streams for street work. The shut-off pipes are used for inside work in a building. They have a gate valve so arranged that the size of the stream can be regulated, and if necessary a ¼-inch stream can be used to wet down debris, etc. The portable pump contains 8 gallons of water and is used to put out small fires. It can be handled and worked by one man.

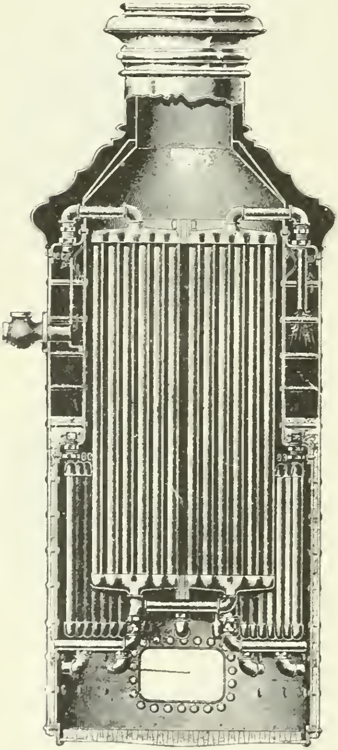
If the hose used at a fire becomes wet, it is taken from the wagon and hung in the tower to be dried, being replaced by an extra dry reel kept in company quarters.

The engines are of the largest size Ahrens or American Fire Engine Co's. build, and have a rated capacity from 900 to 1,100 gallons per minute. The engines are of the ordinary slide valve type and have a double set of pumps, and are supplied with steam by the Ahrens or Fox make of boilers. The motion to the pumps is communicated to the pump piston by the link block or the new American rod motion. The pumps are of the American pattern and are made of gun metal. There are in each pump ten receiving valves, 3 inches in diameter, five of the valves being at the bottom and five being at the top. On the side there are four discharge valves to each pump. These valves are controlled by springs, the tension of which is the same at all times. The water pistons are of a new frictionless type, and have a solid plunger with a composition ring, although leathers have proved to be the best for fire purposes. The Metropolitan fire engines have pumps 5½-inch bore by 8-inch stroke, but the newest engines have a 5-inch bore by 10-inch stroke. These engines are provided with a churn valve to regulate the distribution of water, also a relief valve to work automatically with the pipe at the end of the hose. One of the engines is now provided with an automatic check, which shuts down the engine when the pipe is shut off. A vacuum chamber to give draft to the pumps and an air chamber to regulate the flow of water are provided in all these engines. A coil boiler is used on the Ahrens engine and is one of the quickest known to make steam. It consists of a double shell, stay-bolted, inside of which are sections of 1¼-inch tubing connected at the top to the shell. The tubing is placed horizontally. The water is taken from the leg of the boiler and forced through the coils by a circulating pump into the shell at the top. The fire passing up through these coils causes steam to be made very quickly. The Fox boiler is a steam generator of the vertical water tube type. The boiler consists of a simple annular shell, stay-bolted throughout, and constitutes a water leg fire box and steam reservoir. There are no heads, crown sheet, smoke flues or other inaccessible complications. The principal heating surface of the boiler consists of a straight water tube, manifolded in sectional form and housed in the shell. The position of the tubes is such as to expose their surfaces

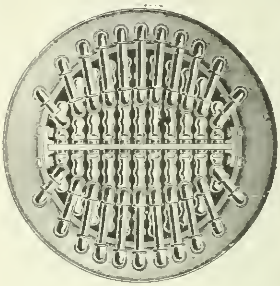


**The Ahrens Coil Boiler.**

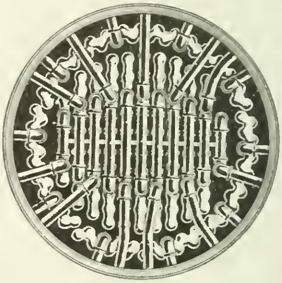
to the direct action of the fire with the least possible disturbance or hindrance to combustion. The direct application of heat to the tubes causes an upward current in them, which in turn induces a downward current in the water in the leg of the fire box, and promotes the flow into the feed pipes arranged to supply the inner system of tubes. The usual complement of tools, nozzles, suctions, reducers, caps, oil, fuel, etc., are carried on these engines. The engine is drawn by three horses.



Vertical Section



Top View



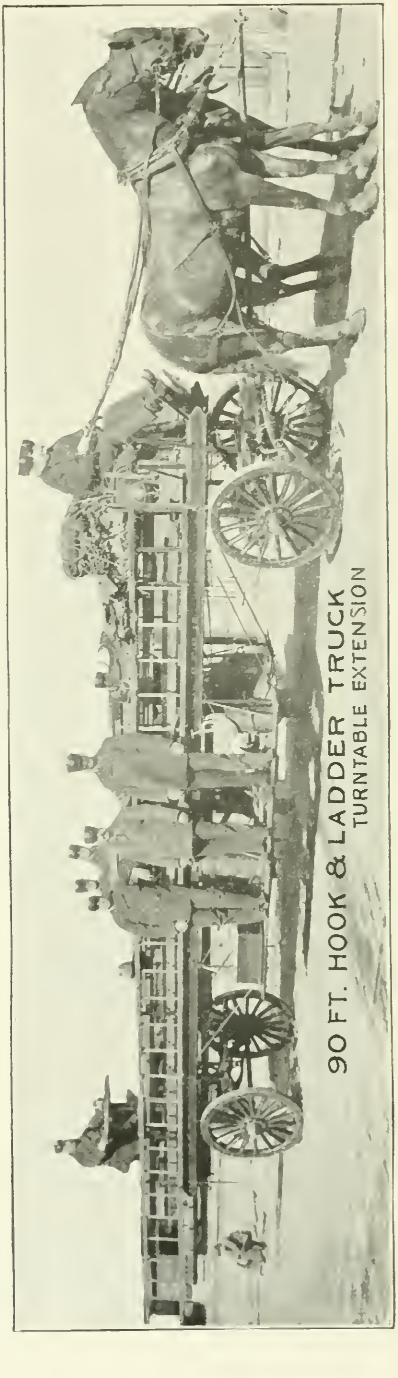
Bottom View.

Upon receiving an alarm of fire by the telegraph register the engine company would on responding secure a hydrant by means of wrapping one turn of the hose around a fire hydrant, leading out to and in front of the fire, and pulling off enough hose to reach the position assigned by the commanding officer. In the meantime the engine connects with the hydrant (which has been secured by the hose-wagon) by suctions. If the company is to work inside the building a shut-off nozzle is used, if from the street a long straight pipe is used. In the event of a more powerful stream being needed, two lines are run to a siamese connection, feeding into a 3½-inch hose with a 1½-inch nozzle attached. If ordered to the roof, a stand pipe on the fire escape is used, if available. If not, the men take pipe, rope, and hose-roller to the roof of the building. The rope is dropped to the street, and attached to the hose, which is pulled to the roof over the hose-roller. When sufficient hose is obtained on the roof, the line is secured by tying under a butt, and dropping it a few feet below the cornice, the end of the rope being made fast to some secure place on the roof. If, however, the fire should be in the basement and too smoky for men to enter, lines of hose are run out as before, to the ends of which basement pipes are attached. A basement pipe is a long "S" shaped pipe so handled that it can throw a stream parallel with the basement though controlled on a horizontal level 2 feet higher. Holes might be cut in the floor and lines of hose run to them on which circulating nozzles are placed. These nozzles revolve by pressure and distribute water in all directions. If the building is equipped with a sprinkler system a second line of hose is run out from the first engine at the fire and connections made, supplying water to the system. This gives an outline of how an engine company would proceed to work at a fire. Conditions, however, change the mode of work.

After a fire is under control and the service of the company is no longer required, upon receiving the order "take up," the engineer is notified. He fills his boiler with water, replaces the suctions on the brackets of the engine, and prepares the engine to return to quarters. The hose would be taken up, placed in the hose wagon and upon return to quarters the engine would be backed in and connected with the heater. A dry reel of hose would be placed in the wagon and the company would again be ready for service.

The hook and ladder companies in the downtown district consist of a truck and a chemical engine, manned by a captain, lieutenant, 8 truckmen and 2 drivers.

The chemical engine consists of a tank mounted upon two wheels and is drawn by one horse. The tank is made of copper, lined with lead to prevent corrosion by the acid. The tanks are ordinarily of 60 to 80 gallons capacity. For an 80 gallon tank the charge is 28 to 30 pounds of bicarbonate of soda placed in the water and 14 pounds of sulphuric acid in a jar, which is placed in a bracket. When the chemical is needed the cylinder tank is rolled over, allowing the acid to mix with the soda and water, forming a carbonic acid gas, which acts as a means of driving the liquid from the tank through the hose which is 1-inch bore. Two extra charges of soda and acid are carried on these chemicals, which may be recharged by removing the cap, filling with water, putting in the soda, replacing the jar in the frame, attaching the cap and using as before.

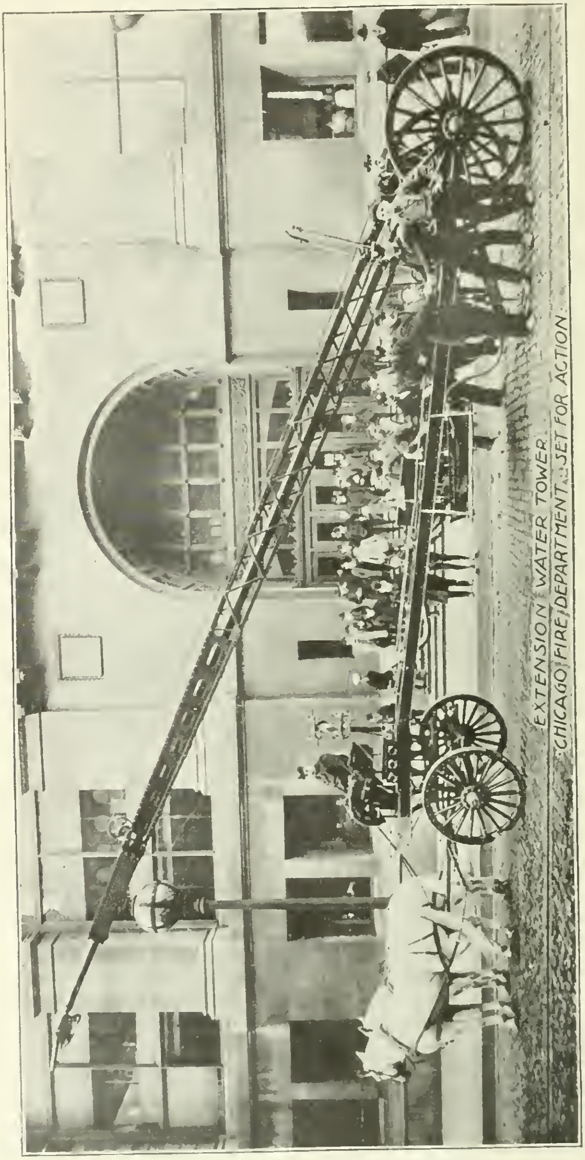


90 FT. HOOK & LADDER TRUCK
TURNTABLE EXTENSION

These chemical engines or "chemicals" carry 200 feet of rope to pull lines of hose to the upper stories of buildings. In case of large fires where it is necessary for the engine streams to work, the men operating the chemical engine station themselves in buildings on either side of the fire to prevent the fire from communicating to the goods in adjoining buildings by the heat, defects in the walls or by sparks.

SCALING LADDER PRACTICE

On the aerial trucks the main ladders are raised by a screw gear and are attached to the truck frame. When in a vertical position or nearly so, the ladder may be turned on a turn-table at its base. These ladders may be raised and placed at any desired angle and in



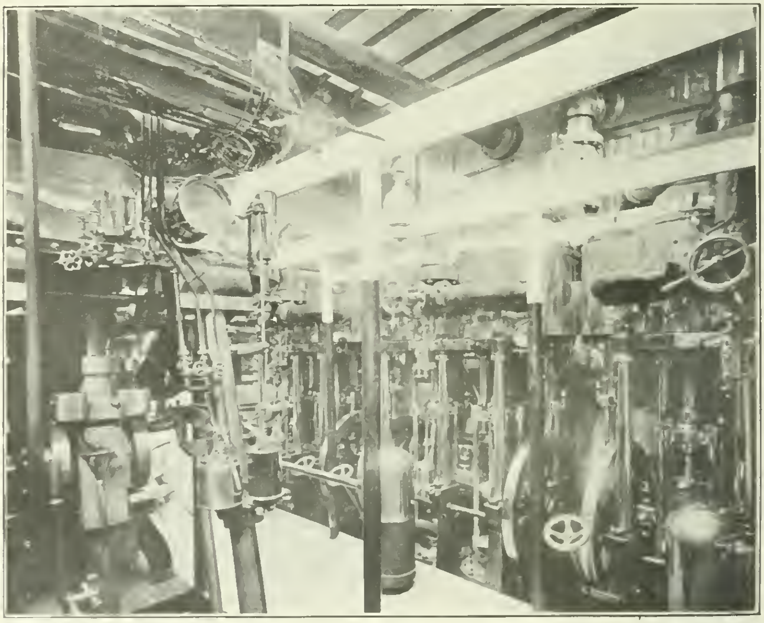
EXTENSION WATER TOWER.
CHICAGO FIRE DEPARTMENT. SET FOR ACTION.

any position by the moving of the truck itself or the ladder on its turn-table. These ladders are 50 feet in length, and can be extended by a fly attached thereto to nearly double that length by means of a cable running over a drum. Dogs are provided to hold the ladder in place when at a sufficient height. On these trucks are carried a 66 foot, a 50 foot, two 36 foot and 26 foot ladders, small ladders with hooks, pompier ladders with full equipment, 500 feet of rope (different sizes), block and tackle, hook and chain for pulling down walls, hook and chain for opening iron shutters, jumping nets, pike poles, axes, shovels, brooms, door openers, wire cutters, picks for brick walls, mauls for sidewalk and dead lights, battering rams for doors, distributing nozzles, basement pipes, siamese connections, hose jacks and pipes, pitch-forks, hay-hooks, crow-bars, saws, screw jacks, hammers and other tools necessary at a fire. A smoke mask is carried on the trucks and may be provided with fresh air so that a man could go into a basement or smoky place and locate gas mains or dangerous chemicals. These masks are similar to a diver's helmet. The 65 foot ladder is a double ladder, the fly of which is raised by a cable and cranks attached. The main ladder is provided with two tormentors or poles, which assist in raising the ladder and also support it while in use. The 50 foot ladder is a similar ladder. Some of these trucks are so equipped that they can be used as a water tower. A nozzle is attached to a bracket at the top of the main ladder and a line of 3½-inch hose run up the ladder to it. The nozzle is controlled by a cable from the ground. The duties of the truckmen on arriving at a fire and under the directions of the officers in charge, are to open doors, windows, shutters, raise ladders, and generally prepare the way so that the pipemen may get to work with their hose.

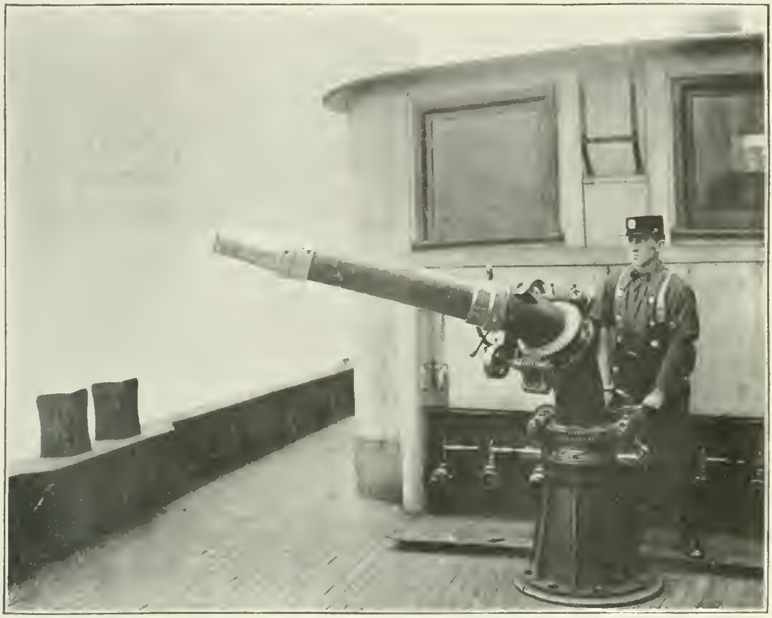
The water tower consists of a large telescope pipe with a flexible nozzle mounted on an iron frame, and is raised in the same way as a ladder of an aerial truck to a height of about 60 feet. A small turret nozzle is also mounted on the frame. The object of the tower is to get a large volume of water on a level with the floor on fire. The water for the tower and turret nozzle is provided by engines or fire boats. The water tower is run in connection with the truck company and is manned by three men.

There are now in service 5 fire-boats, the capacity of which ranges from 2,500 to 10,000 gallons per minute. The boats are built on the lines of a tug boat and are manned by a captain, lieutenant, two pilots, two engineers, four stokers and four pipemen. These boats are used at fires along the river front, and within a distance of about 1,000 feet from the docks. The truckmen assist the boat crews in getting their streams to work. These boats are also used to supply high pressure mains located in the lumber districts and South Chicago. These high pressure mains have three hydrants to a block, where connections can be made with 3½-inch hose and direct pressure used on the fire. These pipe lines are supplied with an electric signaling device.

The fire-boat "Illinois" is one of the most powerful boats in the fire service afloat. It is 118 feet over all, has a breadth of 25 feet, a molded depth of 12 feet 6 inches, a hold of 11 feet and draws about 11 feet of water. The bow is cut away so as to allow the boat to run upon ice in the winter and break it by her weight. On her keel line aft a portion is cut away allowing the boat to turn very easily. The boat is built of steel throughout. It contains two boilers, 11 x 12 feet, of the Scotch marine type, which supply steam to a double high pressure engine 20 x 20 inches, used to drive the boat, and to three sets of the American Fire Engine Co's. pumps, double cylinders 10 x 11 inches, set athwart the ship. These pumps are supplied by water through openings on either side 2½ x 4 feet and located 4 feet below the surface of the water. The water is discharged into a 12-inch pipe, which encircles the entire boat under the deck. This pipe feeds a turret nozzle with a 5½-inch opening and 8 ports for 3½-inch hose forward, and a turret nozzle with a 4-inch opening and 6 ports for 3½-inch hose aft. These turret



Interior of Engine Room of Fire Boat "Illinois."



Forward Nozzle on Fire Boat "Illinois."

nozzles are so arranged that they can be revolved through a complete circle on a vertical axis and also a circle on an angle of 45 degrees. About 4,000 feet of 3½-inch hose is carried with a full assortment of pipes, hose, jacks, etc. Hose spreaders are also carried so that two 2½-inch lines of hose may be obtained from one 3½-inch line.

TEST OF FIRE BOAT "ILLINOIS."

Throwing 12 streams at one time, 8 of them being 2-inch streams, 4 of them 1½-inch streams.

Distance, 200 feet.
Steam pressure, 110 lbs.
Water pressure, 150 lbs.

One 5½-inch stream thrown from forward turret, 525 feet.

Steam pressure, 115 lbs.
Water pressure, 135 lbs.

Fore, one 4½-inch stream. Aft, one 4-inch stream.

Distance, 397 feet.
Steam pressure, 120 lbs.
Water pressure, 135 lbs.

One 4½-inch stream thrown from forward turret, 410 feet.

Steam pressure, 120 lbs.
Water pressure, 155 lbs.

One 4-inch stream thrown from aft turret, 465 feet.
Steam pressure, 115 lbs.
Water pressure, 175 lbs.

Two hose tenders are provided for these boats, one at South Chicago to be used in connection with the high pressure mains, and one down town for the pipe line in the lumber district and for the fire-boat "Illinois." These wagons carry about 1,000 feet of 3½-inch hose with a full equipment of nozzles, etc. The object of these tenders is to facilitate the work of the fire-boats by having a line already stretched before the boat arrives.

In the residence districts the companies are much further apart and cover a greater amount of territory than the down-town or business district companies. The apparatus is built on a much lighter scale, but on the same general lines as the heaver apparatus. The engines have a capacity of about 600 to 800 gallons per minute and are manned by a crew of nine or ten men. The greater part of the hook and ladder trucks are straight frame construction and carry as their longest ladder the double 65 foot ladder already described. There are a few hose carriages with a reel of the older style in some of these companies. These are drawn by two horses.

To protect the suburban districts combination apparatus are used. These engines have a capacity of about 500 gallons and carry their hose in a box on the front part. This apparatus is manned by six men. The trucks are a small straight frame and are provided with a reel of hose and a chemical tank. The longest ladder is a 50 foot double ladder. This company is handled by four men. The hose companies have a hose cart carrying also a chemical tank. Volunteer companies have an equipment of hand apparatus.

The Board of Fire Underwriters maintain a fire insurance patrol of seven companies. This is a very valuable auxiliary to the department.

### STATEMENT SHOWING THE MANNER IN WHICH FIRES WERE EXTINGUISHED DURING THE YEAR 1901.

| | |
|---|---|
| By occupants and others before arrival of Department | 701 |
| By Department smothering, cutting out with axes, etc | 169 |
| By Department with pails of water | 81 |
| By Department with fire-hydrant stream | 220 |
| By Department with fire-hydrant stream and chemical | 31 |
| By Department with portable pumps | 1,959 |
| By Department with portable pumps and portable chemical extinguishers | 163 |
| By Department with portable chemical extinguishers | 23 |
| By Department with one chemical engine | 354 |
| By Department with two or more chemical engines | 9 |
| By Department with one steam engine | 869 |
| By Department with one steam engine and one chemical engine | 236 |
| By Department with one steam engine and two or more chemical engines | 54 |
| By Department with two or more steam engines | 325 |
| By Department with two or more steam engines and chemical engines | 283 |
| Chimney fires, prairie fires, burning rubbish, etc, | 659 |
| Total | 6,136 |

All the hose damaged at fires and after it is dried, is sent to the hose-house, located at the quarters of Engine Company No. 1, where it will be inspected and if found serviceable repaired by cutting off damaged parts and recoupling. There is at the present time 202,695 feet of hose in the service.

A repair shop is maintained, where apparatus can be repaired at any time. The rebuilding of apparatus which may be worn out in the service is also provided for.

There is no training school for horses, but the horses are drilled in the company quarters. There are about 500 horses in service. A horse hospital is maintained in connection with one of the engine companies.

There are now in service 19,324 fire hydrants. In addition to these there are 117 cisterns, accommodating four engines each. A cistern consists of a well built of brick, supplied with water by opening the end of water main, and may be drained by a trap valve at the bottom when not in use.

Now with all this expensive equipment, the fire department has not kept pace with the growth of the city, nor has the department improved to any great extent in the method of extinguishing fires, but it can be improved by revising the building laws and compelling owners of buildings of large area and height to place a standpipe for each floor and connect same with lateral pipes, perforated, or with circulating nozzle, covering every square foot of surface on each floor, with connections marked at the base of the building, water tight floors with scuppers to carry off the water and ventilating flues built in the walls to relieve the building of smoke. Then the fire engines could connect their hose to the pipes leading to the floor on fire and extinguish same before the firemen could take a lead of hose up to the third floor.

## ADDENDA.

### FIRE BOAT FOR MILWAUKEE.

The illustration of the fire boat shown is one designed for the city of Milwaukee, and is very similar to the "Illinois," belonging to the City of Chicago. Both of these boats were designed by Mr. W. J. Wood, N. A., of Chicago, through whose courtesy the illustration and description are furnished.

As shown in the engraving, the hull is of steel construction throughout, and substantially built to withstand hard service, ice-breaking, when necessary, etc. To accomplish the latter, the forefoot is cut away to assist the boat in sliding up on the ice, which is then broken by its weight. The keel and stem are of one piece of

6x1½-inch steel bar. The stern post or rudder post is of cast steel 5½x3½-inch section. The rudder frame is forged with stock 7 inches diameter at head and 4 inches diameter at heel and pintle. The rudder is extra large, 8½ feet wide fore and aft, and made of steel plates of 13½ pounds weight per square foot. The hull is of open hearth steel of a length of 118 feet over all or 107 feet between perpendiculars; beam molded 24 feet and 26 feet over all; depth molded 13 feet 6 inches, with a hold depth of 12 feet 9 inches. Draught 10 feet forward and 10 feet 6 inches aft. The hull is well braced and tied together with four transverse water-tight bulkheads. The coal bunkers are carried alongside the whole length of the boiler space, which, with their water-tight doors, form a cofferdam on each side amidship. The shell plating is worked in outside and inside strakes, with vertical seams butt-strapped.

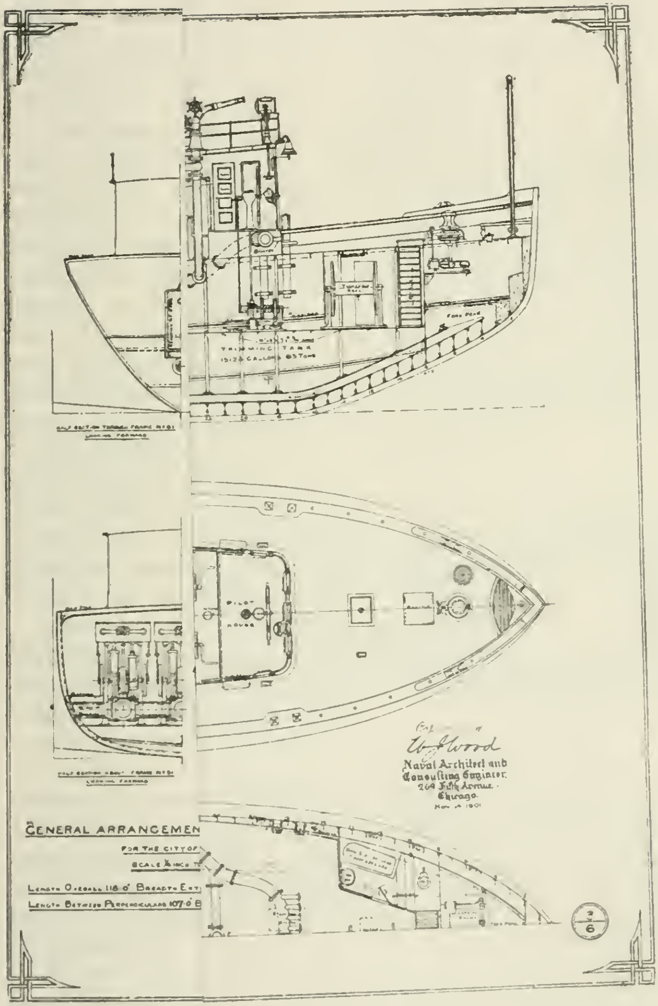
On deck there is provided a continuous house of steel construction 72 feet 6 inches long by 14 feet wide, and 6 feet 9 inches high. The pilot house is at the forward end and finished in mahogany, with interlocking rubber tile floor in colors. The steering wheels are here, which are connected by gearing and vertical shaft to a combination steam and hand combined steering gear placed below.

Abaft the pilot-house is the hose room, containing two large reels for the hose. These are fitted with crank handlebars and brakes, and work on anti-friction bearings. The remainder of the space in the deck-house comes over the boilers, pumps and engines. Skylights are placed over the engine and boiler rooms. A yawl and life raft are carried on top of the deck-house for emergency service. On top of the pilot-house is placed a 13-inch 20-ampere searchlight, to be operated and controlled from the inside of the pilot-house.

Also on top of the deck-house are placed at each end rotary brass turrets, the forward one with an 8-inch, and the after one with a 10-inch supply pipe. (These turrets are the same as illustrated for the "Illinois.")

A steam capstan windlass (naval style) is provided to handle 25 fathoms of 1-inch stud-link anchor chain, with an 800-pound anchor. An anchor davit with all necessary tackle is so arranged that when not in use it is lashed under a grating. There is also a complete equipment of bits, chocks, fair-leaders and timber-heads, the last exceptionally strong to sustain a pull in any direction, or to be used in towing if necessary. Runways and special scuppers to rapidly free the decks of water are provided. A low steel bulwark of heavy scantling is carried round the vessel, topped by a wide and heavy oak rail. Strong and heavy wood fenders supported by two angle irons riveted to the hull protect the hull and

Fire Boat.


TRIMMING TANK
15124 GALLONS 63 TONS
FORE PEAK
PILOT HOUSE
W. J. Wood
Naval Architect and
Consulting Engineer.
264 Fifth Avenue.
Chicago.
Nov 1901
GENERAL ARRANGEMEN
FOR THE CITY OF
SCALE
LENGTH OVERALL 118 0' BREADTH E
LENGTH BETWEEN PERPENDICULARS 107-0' B
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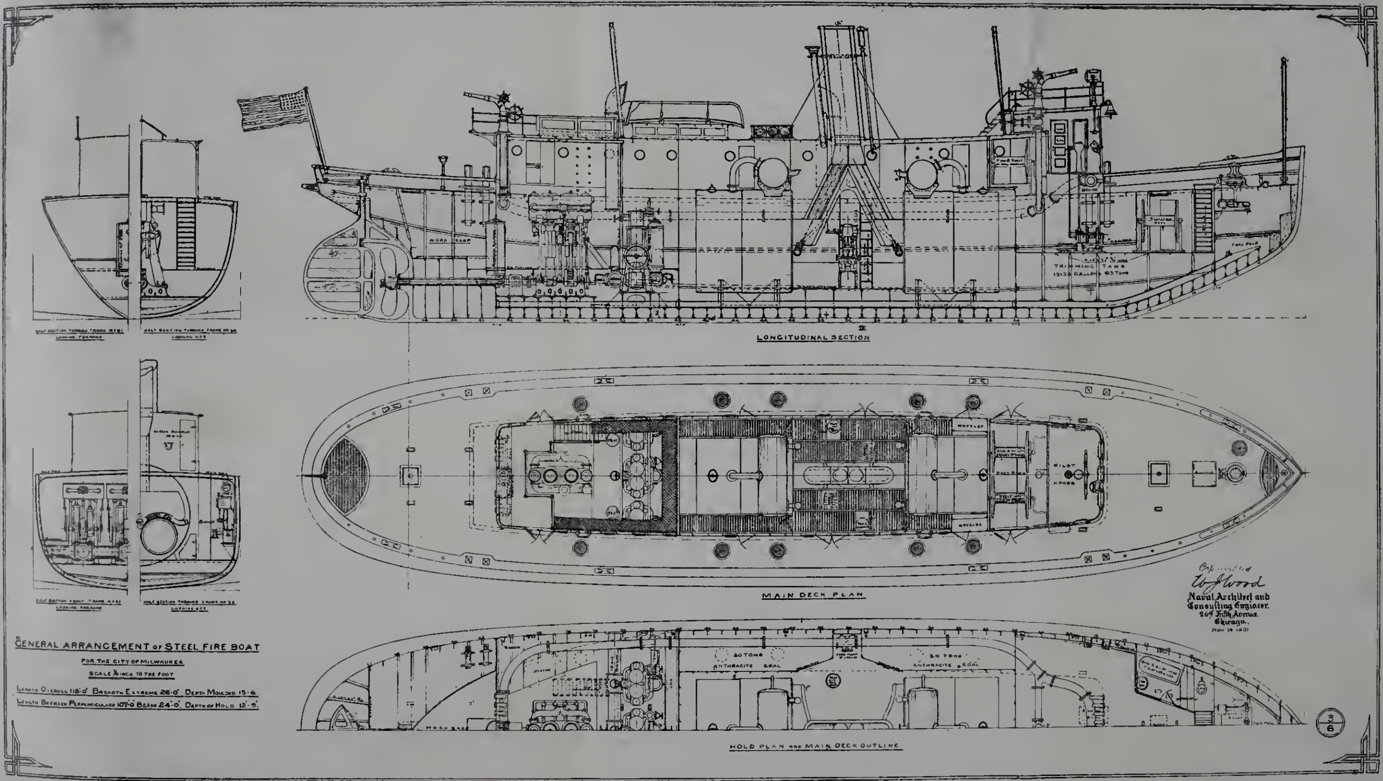
Western Society of Engineers.
Vol. VII. No. 6.
Fire Boat.



bulwarks. Telephone apparatus is installed in the engine room and pilot-house, and arranged to be readily connected with the shore line of telephone wires. There is provided a complete electric lighting plant, including a 7-kilowatt direct-current generator connected directly with a vertical single-cylinder engine 4-inch bore by 4½-inch stroke, operating at 550 revolutions per minute with steam pressure of 80 pounds. This will furnish the electric current for the searchlight, as also the 70 electric lights of 16 candle power placed throughout the vessel.

The main engine is of the vertical inverted duplex, high-pressure type, with cylinders 20 inches bore by 20 inches stroke, operated with a boiler pressure of 140 pounds, and driving a single screw propeller of cast steel 8 feet diameter and 10 feet pitch, 4-bladed and extra heavy to permit service in ice, and designed to give the maximum efficiency when backing. Forward of the propeller engine, but in the same compartment, are three massive fire pumps, set athwartship. These are duplex, double-acting, simple, crank and fly-wheel pumps, with steam cylinders of 17 inch bore by 11 inch stroke. The pump ends are of composition metal, 10 inch bore by 11 inch stroke. Each pump will have a minimum capacity of 3,000 gallons per minute at a pump pressure of 170 pounds per square inch, with a boiler pressure of less than 125 pounds. The auxiliaries include two Worthington "Admiralty type" duplex pumps, placed one on each side of the boat in the stokehold. Another Worthington sanitary pump is included, with sea and fresh water tank connections.

There are two boilers of the Scotch marine type, each 12 feet diameter of shell and 11 feet long, internally fired and fitted with Morrison corrugated furnaces 47 inches diameter by 8 feet 8 inches long. The Shelby seamless return tubes are 228 in number, 2¾ inches outside diameter by 8 feet 2 inches long. The boilers are set front to front, with 13½ feet length of stoke hold. The boilers are made of 60,000 pound "marine steel," and are to stand a working pressure of 140 pounds. The smoke connection from each boiler connects to one common funnel 36 inches diameter, with an outer casing of 48 inches diameter. The stoke hold will be provided with hydro-pneumatic ash ejectors, as well as an arrangement for lifting the ashes by tackle through the ventilators.

Aft of the engine room is a completely fitted up work-shop, with air ports and deck lights, as well as a square scuttle, fitted with edge rollers, for the handling in and out of the hose. Communication between the work-shop and engine room is by means of a water-tight door, of the Kirkaldy pattern, a cylinder revolving within a cylinder, which secures a passage-way that is never entirely open.

## DISCUSSION.

*Mr. Musham*—As this paper has been printed and sent out in advance, I will say a few words in regard to the Chicago Fire Department. It consists of 92 fire engine companies, including 5 fire boats, 27 hook and ladder companies and 15 chemical engines. The most of these are run in connection with the hook and ladder companies, which really make a fire department in themselves. There are also about 200,000 feet of 2½ and 3-inch hose. Ten of the hook and ladder companies have what we call the turntable extension trucks; these are lifted to a height of from 75 to 95 feet. This equipment is operated by about 1,200 men at an expense of a little less than $2,000,000. With all this expensive equipment the Fire Department of Chicago, and all other cities, has barely kept pace with the growth of the business. Our system of fire extinguishment is about the same as when we first started it, although our engines are larger, heavier and of greater capacity. But still, when we are called upon to extinguish a fire—say in an eight-story building used for commercial purposes—it is almost an impossibility to bring water enough to bear to extinguish a fire in the upper floors. What is the consequence? We are driven from one floor to another and finally into the street. The interior of the building is destroyed, leaving nothing but the bare walls. Now gentlemen, what is the remedy? In my opinion the remedy is the high-pressure system, separate and distinct from anything else, with pipes running to the floors of each building; also lateral pipes connected with sprinklers, circulating nozzles, etc., and with connections at the base of building for fire engines or high-pressure fire hydrants when installed. Such arrangement to cover every square foot of surface and bring the water to bear right on the fire. I think, gentlemen, that is the coming future fire protection system.

Now as to our fire alarm system. I think we have the quickest fire alarm system in the world, owing greatly to the ability and the energy of our City Electrician, Mr. Ellicott. I do not think there is any question about that. Mr. Ellicott will explain that system.

This commercial centre here is protected by 6 fire engines. Now, with the high pressure system, you could multiply that by 4, which would give us 24 hose companies. These could use either hose wagons or hose carts, and with that number of hose carts and the high pressure system, this district would be able to take care of itself. No city in the country will be properly protected unless each district has a sufficient force to manage any fire that may occur in that district.

*Mr. Isham Randolph*—How long does it take you to get up steam so you can fight a fire?

*Mr. Musham*—The steam is on all the time; there is about 15 pounds pressure generated from the heater. We are always ready.

*Mr. Randolph*—Is the automobile used at all?

*Mr. Musham*—Some years ago the city purchased three self-propelling fire engines, but they were not a success for two reasons: one was that the entire machinery was in motion while on the road to a fire, pumps and all, and it wore the leathers so that when they were placed in action they obtained insufficient pressure from the pumps; the other reason was that from the high pressure of steam maintained, the boilers were continually leaking.

*Mr. Randolph*—Are they not experimenting now in New York and Philadelphia with the automobile?

*Mr. Musham*—Not in New York. They are doing this in Boston and in Hartford, Conn., I believe. New York discarded them about the same time we did.

*Prof. Chamberlain*—What is the fuel used?

*Mr. Musham*—Coal and wood.

(Referring to lantern slide of scaling ladder).

There is nothing new about a scaling ladder. I think it must be a thousand years old. It originated in Germany; it is a German invention. In fact it is what was used a thousand years ago to scale walls. It was brought to this country by a man by the name of Hoell, from St. Louis. He introduced it in St. Louis, and from St. Louis we adopted it here in Chicago.

*President Finley*—They use them in other cities do they not?

*Mr Musham*—Any city in America. We can use four ladders and four men and climb to almost any height.

*President Finley*—Do you have many accidents from the ladders giving way or slipping?

*Mr. Musham*—Two men lost their lives at drill, but it was more through their own carelessness and not by the breaking of the ladders.

*Mr. Hatch*—At about what pressure do you deliver the water from the nozzle of the fireboat?

*Mr. Musham*—At about 150 pounds. That will throw twelve 2-inch streams. It has been done on a test.

*Mr. Randolph*—You spoke of the eighth floor being the limit.

*Mr. Musham*—It is not the limit. We have been up 240 feet fighting fires and put them out too. We will suppose that the fire is on the eighth floor, and we have to climb the stairs with our pipes and hose. That is what I meant. We can get one line up there and by the time we get the second line up there the fire is on the next floor, and that is the way we are driven down from one floor to another until we reach the street.

*Mr. Reichmann*—Do you ever use stand pipes which run up the sides of the buildings?

*Mr. Musham*—Oh yes. Owners of buildings of great heights should be compelled to put these pipes in.

*Mr. Reichmann*—What do you think of the sprinkler system in large buildings?

*Mr. Musham*—It is all right.

*Mr. Reichmann*—Is it used very extensively in Chicago?

*Mr. Musham*—Yes, it extinguishes a great many fires.

*President Finley*—Mr. Edward Atkinson, of Boston, was strongly of the opinion that it was very much superior to any other method of fire fighting; that it was very much more efficient than the way you fight fires. What is your opinion about that?

*Mr. Musham*—I do not think the delivery is sufficient for two or three steam fire engines to force water in. I do not think it would free the engines. We could keep up the same pressure that their tanks do, of course, but there are classes of goods that would give to a fire a greater volume than that.

*Mr. Randolph* Are nearly all our grain elevators fitted with sprinkler systems?

*Mr. Musham*—I believe some of them are. I do not know of any fires we have had here in grain elevators that had the sprinkler system.

There is a nozzle in Milwaukee—the Judge nozzle—which really is what you might call a circulating nozzle, which extinguished a fire in Milwaukee in an elevator, and it is the first elevator where a fire got any headway where a nozzle put the fire out.

*President Finley*—Are not all the sprinkler systems in Chicago supplied from elevated tanks? That is, tanks on roofs.

*Mr. Musham*—Yes.

*President Finley*—For instance, take a modern fire-proof grain elevator. Would the sprinkler system put a fire out in such a building?

*Mr. Musham*—I can answer that question only from what I have read. There was a fire in a grain elevator in Minneapolis and the elevator was destroyed.

*President Finley*—Was it a modern fire-proof grain elevator, as they are building them now?

*Mr. Musham*—Well, that fire occurred about ten years ago.

*President Finley*—The construction was not very modern then.

*Mr. Musham*—I think the only appliance that will check a fire in a grain elevator is the Milwaukee nozzle.

*President Finley*—Can you tell me just what that is like?

*Mr. Musham*—It is attached to a pipe and will throw a spray of water 120 feet from the center.

*President Finley*—The nozzle sprays the fire out, I suppose?

*Mr. Musham*—Yes, each way in a circle. I think Milwaukee is the only city where it is used. They gave an exhibition of it in New York at the time of the convention there, before the National Board of Underwriters, and they appeared to be very well pleased with it.

*President Finley*—Do you think, then, that would be more effective than the sprinkler system?

*Mr. Musham*—You must apply force to it. The sprinkler system is self-acting, or automatic. It has stopped a great many fires in Chicago.

*President Finley*—The sprinkler system, I believe, is generally recognized among the Fire Underwriters as being an efficient method of fire protection.

Mr. Page, Fire Marshal of Joliet, was then called upon by President Finley, and responded as follows:

*Mr. Page (Fire Marshal of Joliet)*—If I had to take my choice between a fire department, with engine, etc., and a fire alarm system, and could have but one, I would take the fire alarm system, because without that it is impossible to do any effective work. The fire alarm system, however, is not and cannot well be used in cities the size of Joliet, or in any city under 100,000 inhabitants, as a city of less than that number cannot afford a competent electrician to take care of it. Our fire alarm system we have constructed ourselves, entirely. We make our own boxes, costing about $10 each, and I think we make a better box than the "Gamewell." The "Gamewell" is too high priced a box for our city, as we could have very few of them at the price charged for them. Our system is an exceedingly rapid one to operate, more so than the "Gamewell." They have just been installing a plant at the American Steel & Wire Company's works, and it took exactly three minutes for a box to come in. I make considerable sport of it.

In regard to extinguishing fires. It is getting to be an exceedingly serious matter, and what you use here in Chicago and in large cities we cannot and do not use in Joliet. Of course you know that water will not put out a fire; that it simply reduces the temperature below the point of combustion. It is the chemicals that extinguish a fire. So if a fire has got up to 1,000 degrees in a few minutes you would say, "when you put water on it, it seems to burn faster," and you are correct; it does burn faster. But if they can have a pipe like that shown on the "Illinois," and a pressure behind it to turn on a Niagara Falls, they will put the fire out. That is what we have got to have.

We hope to have, before very long, an auxiliary system in Joliet. This can be accomplished for $10,000. Our water pressure there is rated at 30 pounds and we put out all fires with it. With the chemical engine you have to get right in where the fire is. Our method of handling our department is very different from the systems in large cities, and we get along with a great deal less force—that is, fewer men. Our fire department does more with the money that it has to spend than the police department. Sometimes in the house where my office is—my headquarters—I have been quite frequently for a considerable time during the day entirely alone, with one steamer, one ladder and wagon, one combination hose wagon, and my buggy to drive and myself.

Mr. Musham is right about this auxiliary system. We have got to have large volumes of water, unless some one will get up some plan to apply chemicals the way we do with the water. I believe in such a case we could get along without any water, but we have to have an enormous lot of water and powerful means to apply it. In New York recently they gave some exhibitions there of nozzles and were using two engines to do the work that one ought to.

One great advantage we have at Joliet, is that our hydrants have a 5-inch outlet, that gives a free supply to the pumps so that the engine can exert its full power on the discharge. With small hydrant openings, the supply is throttled to some extent and the efficiency of the engine and the pressure of the water at the nozzle are consequently reduced from what it would be with a full and free supply of water.

# CLXI.

## THE TRANSMISSION OF FIRE ALARMS.

By Mr. E. B. Ellicott, M. W. S. E.*

*Presented Nov. 19, 1902.*

The wonderful progress in the science of extinguishing fires has been materially aided by the improved and increasing facilities that have been devised for the purpose of notifying fire departments of the location of the fire with the least possible delay. In the days of Volunteer Departments the only means of notification was the clamorous ringing of a centrally located fire-bell, which method meant, at least, a considerable delay, and was not always efficient. The fire losses of to-day would be multiplied many times if the existing departments were required to depend upon the old system of alarms. But inventive genius has supplied many different means—both automatic and manual for the purpose of indicating the existence and location of fires, thus placing important and necessary information before the responding fire department in the shortest possible time. Without exception, electricity is the agent which is adopted in the transmission of alarms. Varied forms of apparatus have been designed, but the modern and most commonly used system of to-day is only an evolution of the first electrically operated system of 1852. Our present mechanically and electrically perfect street box, so simple in construction

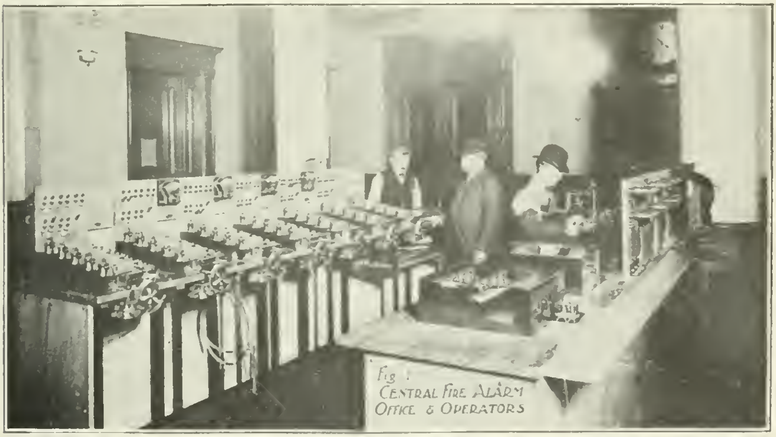


Fig 1
Central Fire Alarm
Office & Operators

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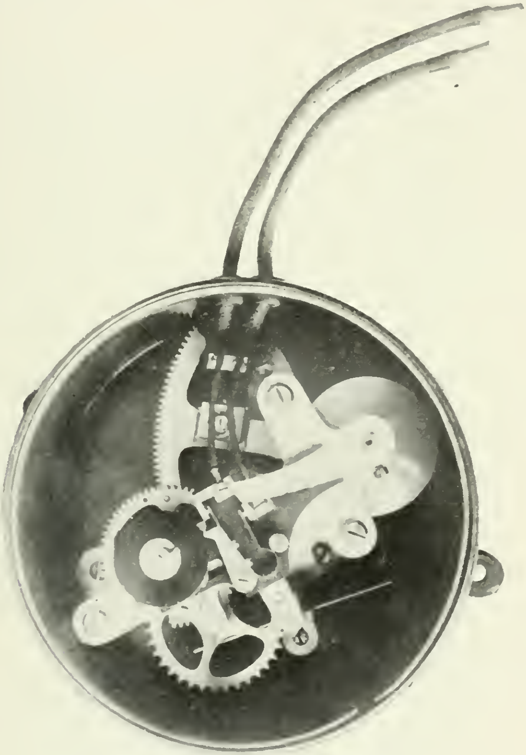
*City Electrician, Chicago.

and operation that a child can operate it perfectly, was represented in the earlier days by a box containing a large wheel, upon the periphery of which were teeth representing numbers or characters, arranged to make and break the circuit as rapidly and often as the wheel was turned. If the individual sending in the alarm was excited and turned the wheel rapidly, the reproduction of the characters in the engine houses was more than apt to be unintelligible. The present boxes are speeded to send the signals which, representing numbers, at a uniform rate, and when the box mechanism has been once actuated it will complete its signal without further attention. The manner of receiving the signals thus sent differs somewhat in various cities, but as a rule the signals are printed in ink on a paper tape, in a manner described later.

Dr. Channing and Moses P. Farmer were the original inventors and patentees of the electric fire alarm telegraph, and such information as can now be obtained would indicate that the system was nothing more than an electric circuit, provided with several mechanical means of making a series of breaks in the circuit (differing in number), thereby identifying the location ; the breaks in the circuit actuated a bell-striking apparatus.

As first applied, the bells were used in connection with the street boxes, but later were also centrally located and could be heard at considerable distances. Central station apparatus, consisting of the ordinary sounders equipped with bells, also the Morse telegraph recording apparatus, was used in engine houses and department headquarters. Part of the original apparatus is still in existence, and its design and construction indicate that little judgment or mechanical ability was used. However, it operated successfully, and like other pioneer inventions, formed a basis for the present perfect apparatus to be found in some of the larger cities. The original system was operated entirely by attendants, and the first important improvement was the automatic repeater, which made actual attendance unnecessary—the alarm from the box being automatically repeated to engine houses. The automatic repeating system was applicable to small cities only, and is still largely used, having been improved and perfected to such an extent that it meets all the requirements of small cities, where but few alarms are received.

The modern system is a complicated one and somewhat difficult to understand from a description, even with the aid of a fair knowledge of electrical matters. The most important factor in the complete system—the street or signal box—is the least complicated. Its construction is simple, and if carefully made its operation is practically certain. In the modern box there is a segment of a gear wheel, set in mesh with a small geared ratchet, which is arranged to engage the reduction wheel when the segment has been pulled down far enough to give at least one complete revolution of the character wheel. Thus it will be seen that it is impossible to actuate the mechanism without making a complete record of the box number.



Mechanism of Fire Alarm Box.

Most boxes are designed to repeat the number of the box four times. An escapement wheel is provided, by means of which the speed of the box may be varied to suit operating conditions. The pulling down of the segment of gear winds up a spring which furnishes the necessary power to restore the mechanism to its position of rest, during which operation the character wheel has been revolved several times, and in revolving has opened and closed the electric circuit a number of times corresponding to the teeth on the character wheel. The teeth are spaced to represent a certain number which identifies the location of the box. It is apparent that the box is a very simple piece of mechanism. But the box has other complications, other uses than actually transmitting the alarms, and requires careful protection. There must be provided a means of sending other signals than the one on the character wheel, and a telegraph key is provided for this purpose. It is also necessary to receive information or acknowledgment of special signals sent, and for this a sounder or bell is provided.

The electrical circuit and contacts of the box are of a delicate nature and must be protected from an excess of current due to possible cross contacts with wires of higher voltage, and means of automatically shunting such currents from the parts liable to injury must be provided; also lightning arresters, where boxes are placed on overhead circuits. The mechanism must be enclosed in a dust-proof box, with the actuating shaft extended through, and this protecting box must be enclosed in another box in which are placed the shunting devices, key, signal bell and lightning arresters. On the door of this inner box is placed the hook used to operate the box when it is desired to send in an alarm. This hook is arranged to engage the actuating shaft and to disengage itself when pulled clear down. An outer protecting box is provided for the entire inner box and mechanism. Thus a comparatively simple mechanism is complicated by the conditions surrounding its own protection and possible uses other than repeating its own number for the purpose of identifying its location.

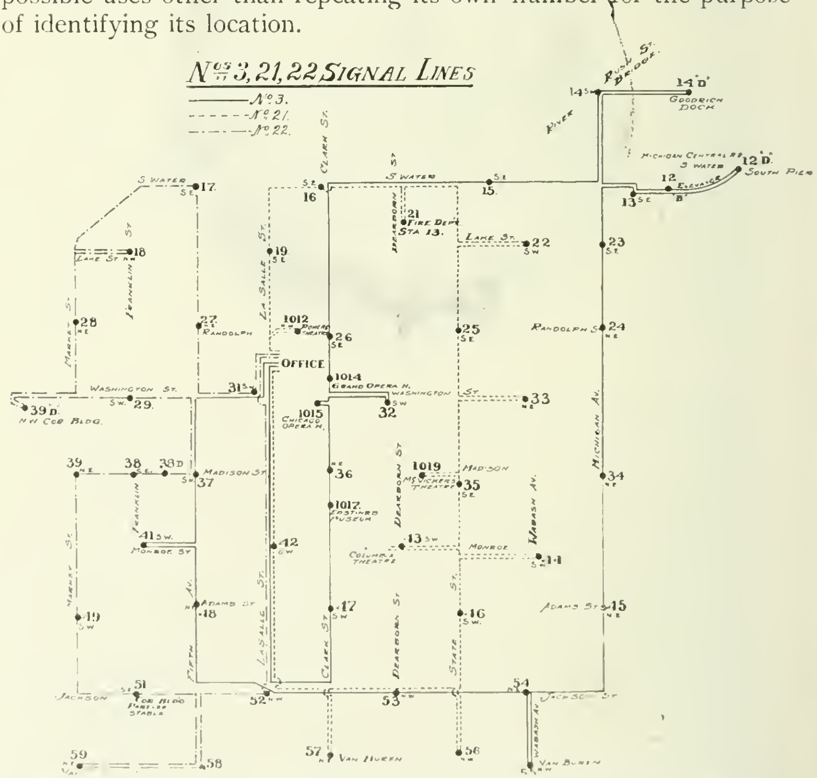


Fig. 3.—Diagram showing three signal box lines to Central Office in the down-town district, about three-quarters of a mile square.

Each street box is but a repetition of the foregoing description, and a number of boxes are usually placed on a single line. This line is termed a signal line, and terminates in a central office, where instruments are provided for the purpose of recording such signals as may be transmitted either by means of a box having been pulled, or use of the telegraph key placed in each box.

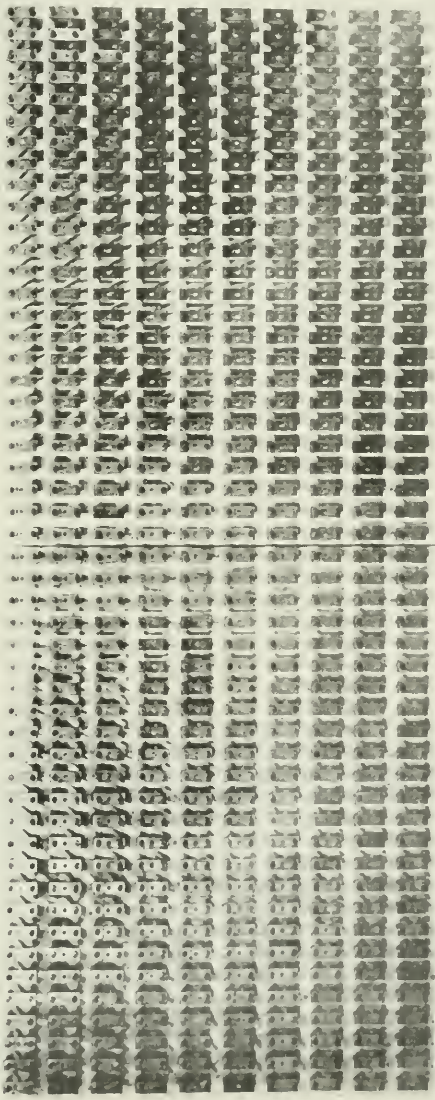
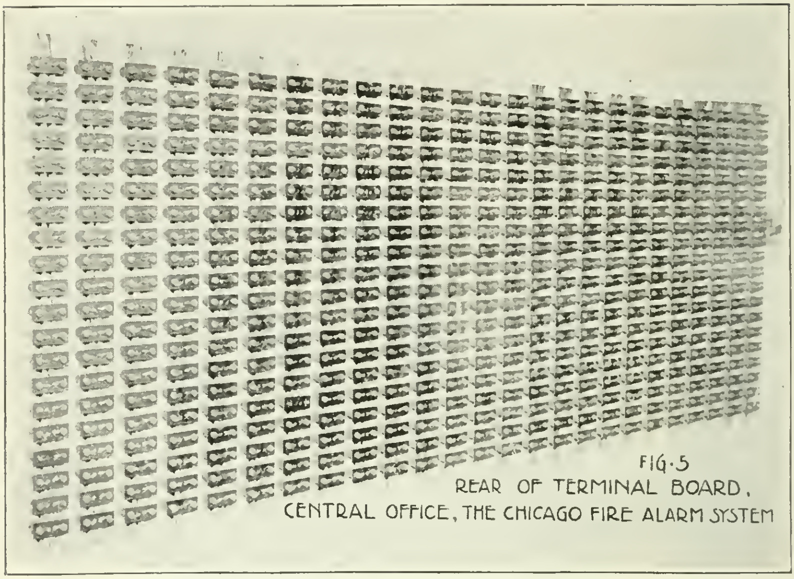


Fig. 4. FRONT OF TERMINAL BOARD, CENTRAL OFFICE. THE CHICAGO FIRE ALARM SYSTEM.



FIG·5
REAR OF TERMINAL BOARD,
CENTRAL OFFICE, THE CHICAGO FIRE ALARM SYSTEM

In the modern office, each signal line, after passing through a suitable terminal board, is brought to a distributing board, where provision has been made for connecting testing instruments, inserting batteries, circuit protecting devices, and means of switching circuits together, finally terminating in a sensitive relay adjusted to immediately indicate, by means to be further described, any actual break in the circuit, or even a small decrease in the normal current on the line. Assuming a box has been pulled, the first break of the character wheel allows the armature of the relay to make an

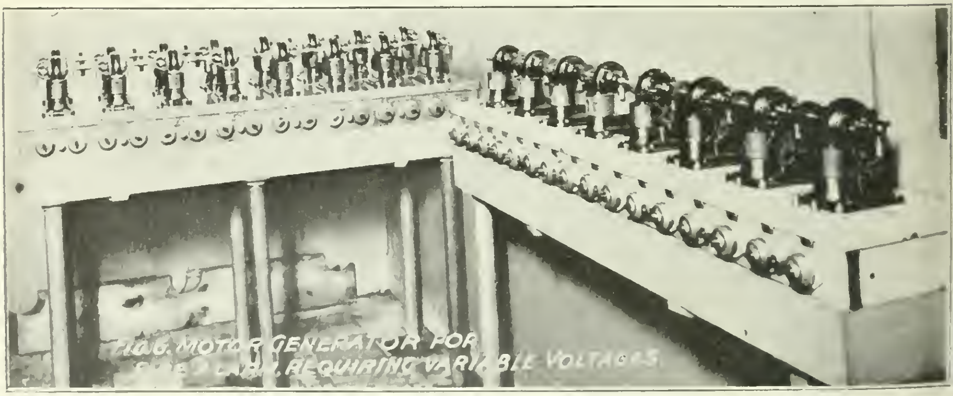
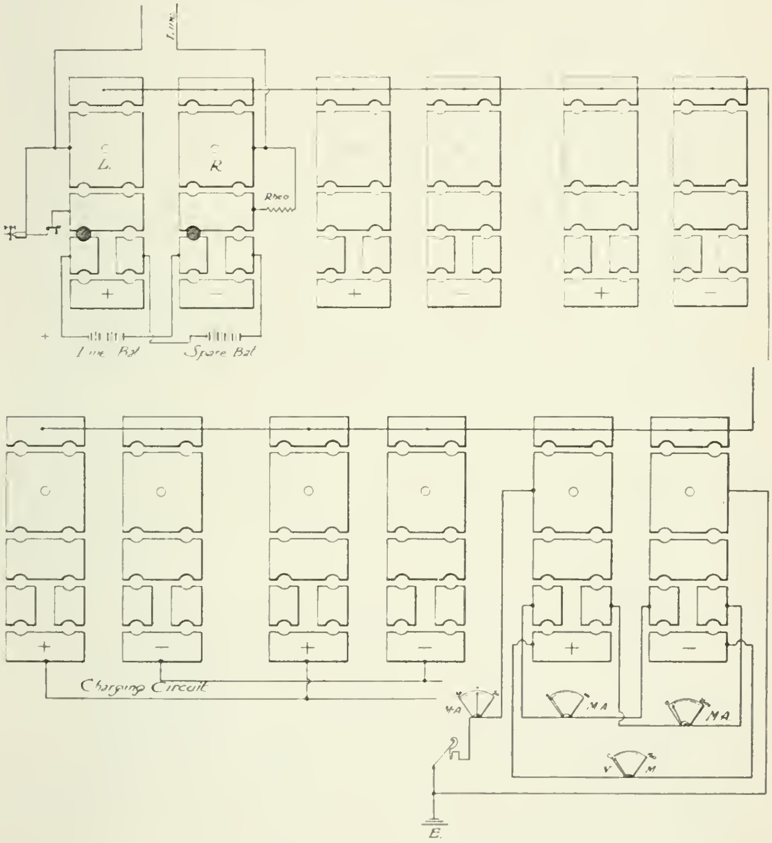


FIG.6. MOTOR GENERATOR FOR
[illegible] REQUIRING VARIABLE VOLTAGES.

electrical contact bringing into circuit a bell, an annunciator indicating the number of the line, and a small incandescent lamp showing both line and individual instrument—two visual and one audible notifications that a break has occurred in the line. These different signals are not dependent upon each other, and the failure of one will not interfere with the operation of the others.



SIGNAL LINES Nos 1 TO 30

Fig. 7.—Diagram showing Terminals, Switching and Testing Facilities at Central Office.

At each relay is located a three-point switch, normally standing on the point to which the alarm bell is connected. If the break in the circuit is identified as a box number, the switch is turned to another point, which brings a printing register into circuit, and a permanent record of the box is obtained. To the second point of

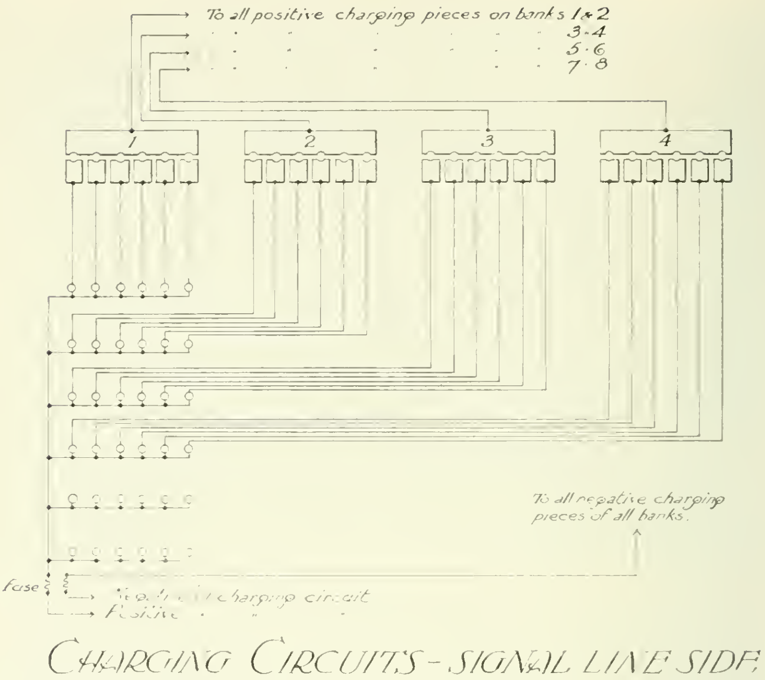

To all positive charging pieces on banks 1 & 2
3 · 4
5 · 6
7 · 8
1
2
3
4
To all negative charging pieces of all banks.
Fuse
To negative charging circuit
Positive
CHARGING CIRCUITS - SIGNAL LINE SIDE

Fig. 8.—Diagram showing charging lines for storage batteries at Central Office.

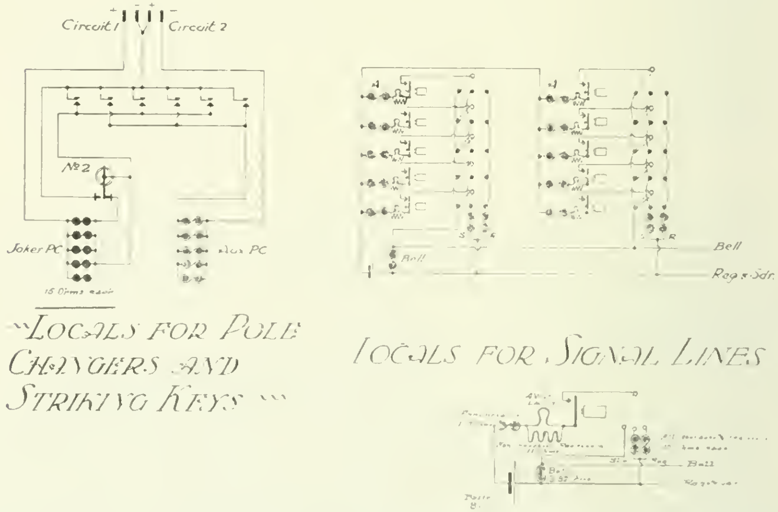


Fig. 9.—Diagram showing local wiring connections for pole changers and signal lines at Central Office.

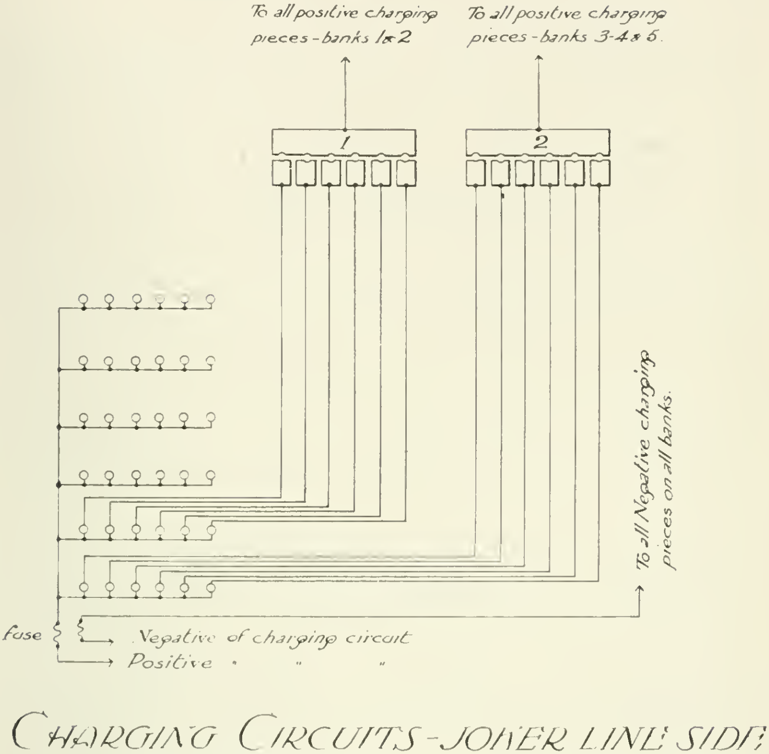

To all positive charging pieces - banks 1 & 2
To all positive charging pieces - banks 3-4 & 5.
1
2
To all Negative charging pieces on all banks.
fuse
Negative of charging circuit
Positive " " "
CHARGING CIRCUITS-JOKER LINE SIDE

Fig. 10.—Diagram showing charging lines for Storage Batteries at Central Office.

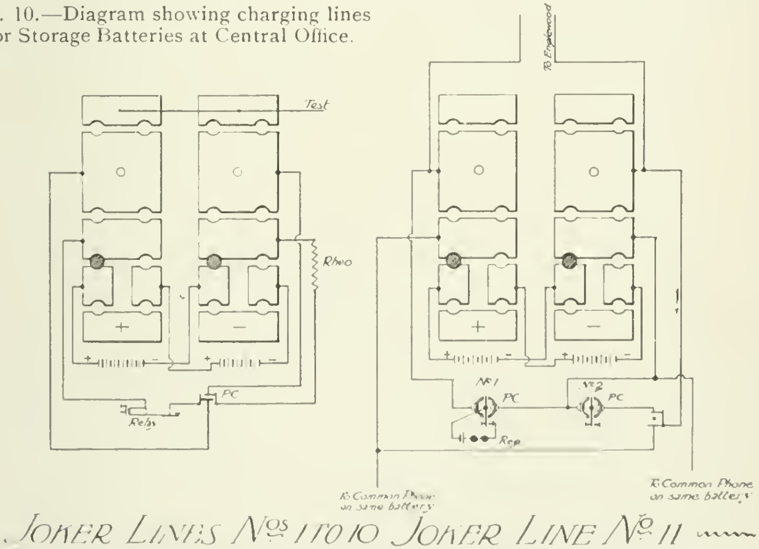


Fig. 11.—Diagram showing Terminals, Switching and Testing Facilities at Central Office.

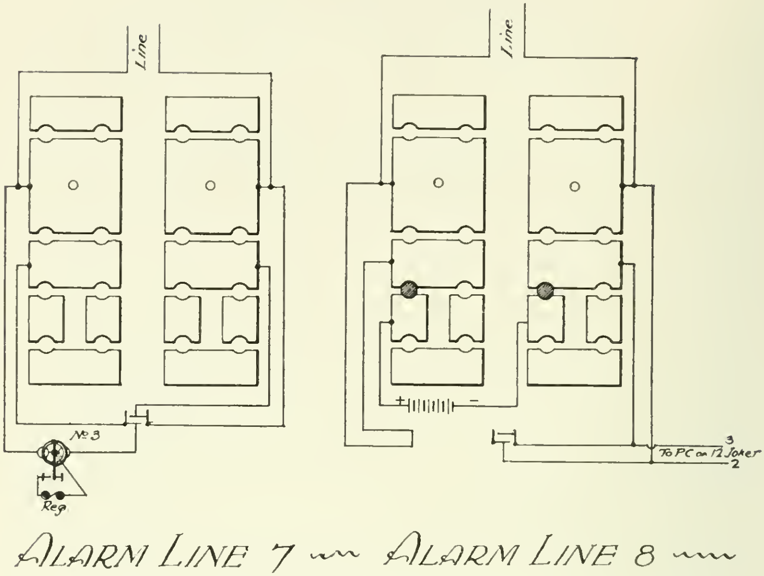


Fig. 12.—Diagram showing Terminals, Switching and Testing Facilities at Central Office.

the switch a sounder is connected, and is used for general telegraph purposes, such as communicating with repairmen working on the line, and in some instances to receive special alarms sent from boxes by telegraph code.

An alarm having been received, it must be sent to each and every engine house, battalion chief's quarters and police stations, and here the real complication begins. Not only must the alarms be transmitted, but they must be automatically registered in each location, and to avoid possible errors or failure of individual instruments, each alarm must be repeated over an entirely different line with provisions for a second printed record and an additional gong alarm to insure attention, under conditions to be described later. Means must be provided for the engine companies to advise the main office on their return from a fire, and, as this is important information, two separate means must be provided for sending it. After a company has returned from a fire and reported to the main office, every other engine company must be notified of the fact, as under some circumstances the movements of a company depend upon the absence from quarters of another company. To devise means of transmitting this information reliably, quickly and without too great an expense in construction and maintenance of lines, has required skill and inventive ability. The problem was first solved by Prof. John P. Barrett, of Chicago, former Superintendent of City Telegraph, who invented the "Joker" system now in use in nearly all large cities. This system, with some modifications to suit local conditions, is described as follows:

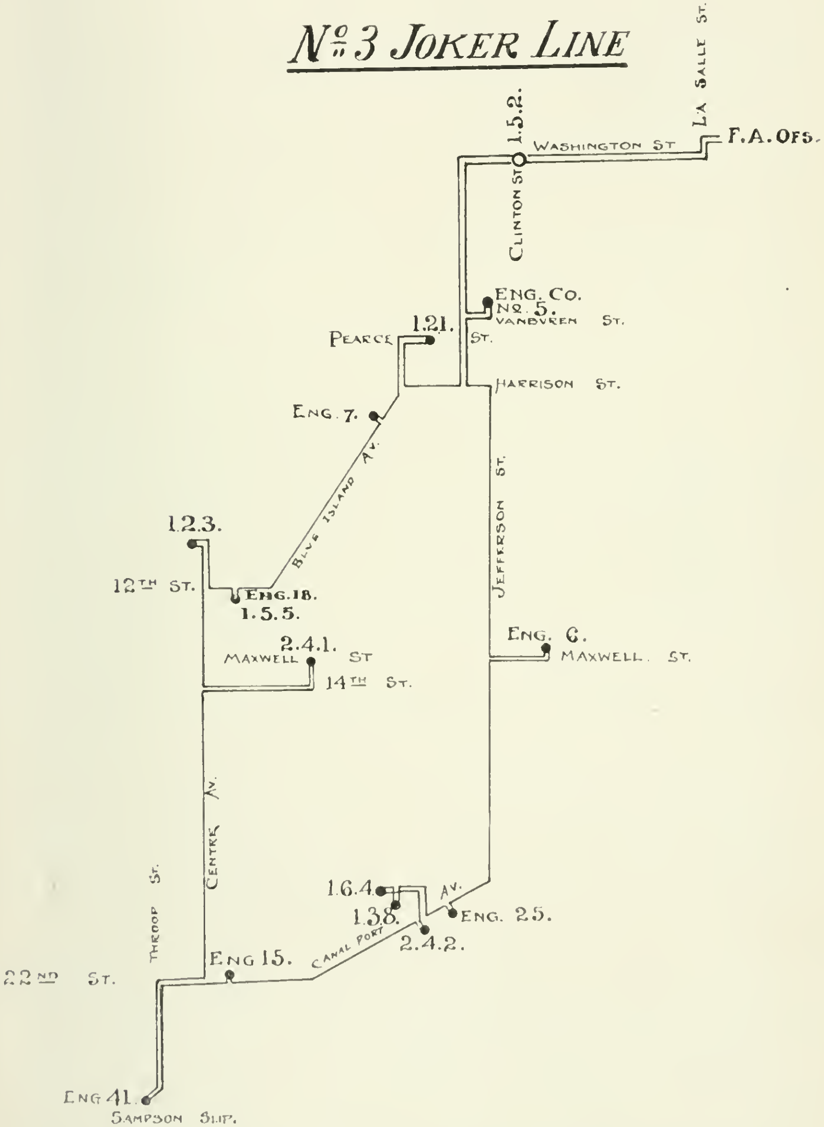


Fig. 13.—Diagram of wiring of one of sixteen districts, showing manner of connecting Engine Houses on "Joker" line circuits to the Central Office

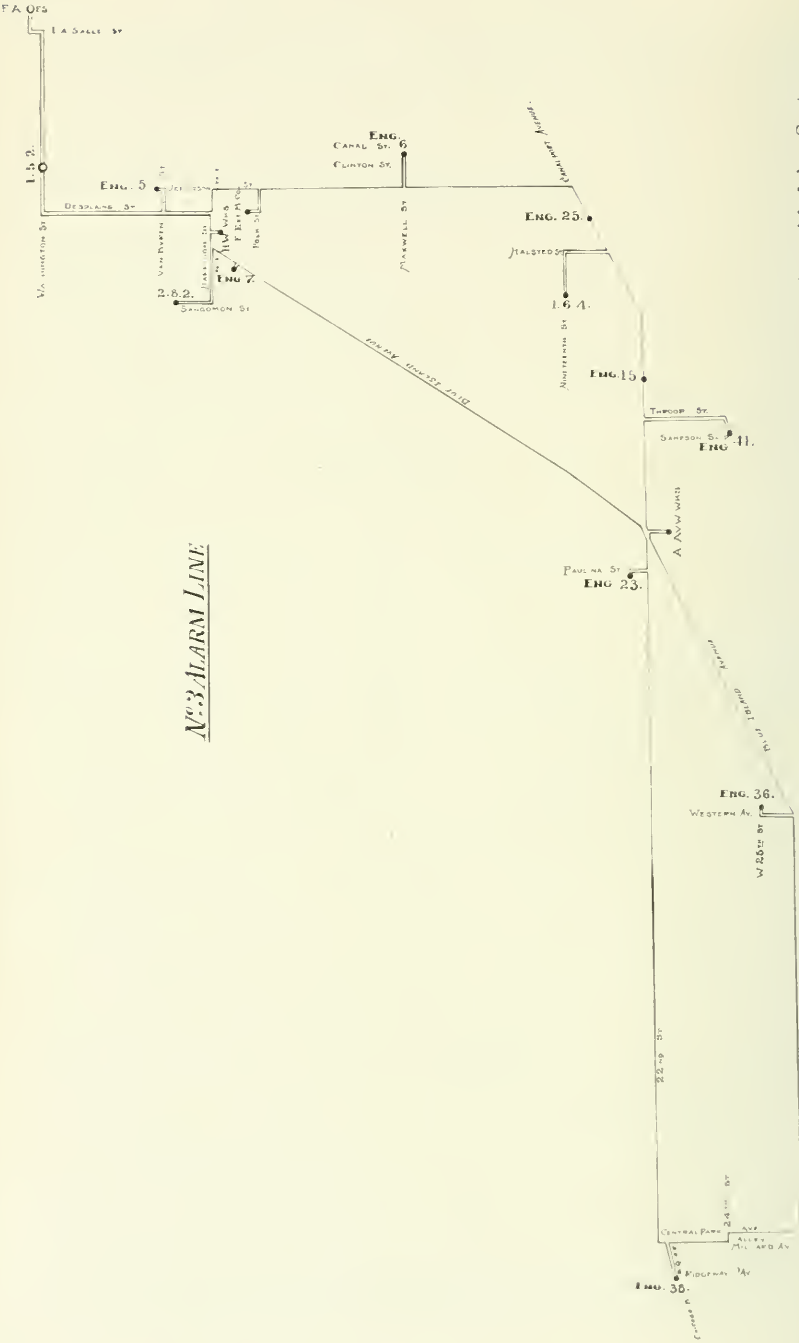


Fig. 11.—Diagram showing duplicate system of transmitting alarms to Engine House, used in connection with Joker System.

A circuit is established through a certain number of engine houses and terminates in the main fire alarm office, at which point it is provided with the same switching and testing facilities described for signal lines. The battery or source of current is carried to an electrically operated pole changer, used for the purpose of reversing the current in the line, or in fact sending over the line an alternating current. This reversal of the current makes possible the use of the line for two separate classes of signals, as follows:

At each engine house there is placed in the alarm line circuit a polarized relay that responds to each reversal of current in the line, and has connected to its local points a printing register. Therefore when the current is reversed a given number of times at the main office, each polarized relay in the circuit responds, closing a local circuit in each engine house and automatically printing the number of reversals on a paper tape. It is in this manner that the number of the street box is simultaneously transmitted to each engine house. These lines are not used for any other purpose than the printing of the box number.

There is another line similarly constructed and operated except that it performs two functions. In addition to its polarized relay for each engine house it has a direct current relay and a telegraph key, by means of which the Morse code and a special department code is made available for transmitting instructions, certain reports and alarms not requiring the services of more than one engine, and for receiving the reports of engine companies when they return from fires.

The work of the polarized relay in this circuit differs from that performed by the one first described, as in addition to printing the number of the box, it actuates a second circuit in which is placed a large gong acting as a "waker" for the men. This gong is normally in circuit and will always sound unless the attendant on watch switches it out, which is always done if the company does not respond to the box struck. There is also a small table bell in this line which furnishes a second means of reading the alarm in event of the register failing.

The receiving and sending of an alarm is briefly described as follows: Simultaneous with the pulling of the street box the annunciator on that line at the main office falls and an alarm bell rings calling attention of the operator, who switches the register into the local circuit of the relay and obtains two perfect records of the box number. At each bank of relays there is located a key controlling the pole changers in circuits running to all engine houses. The operator reproduces the box number twice on each key, using first the key that controls all alarm lines in which there

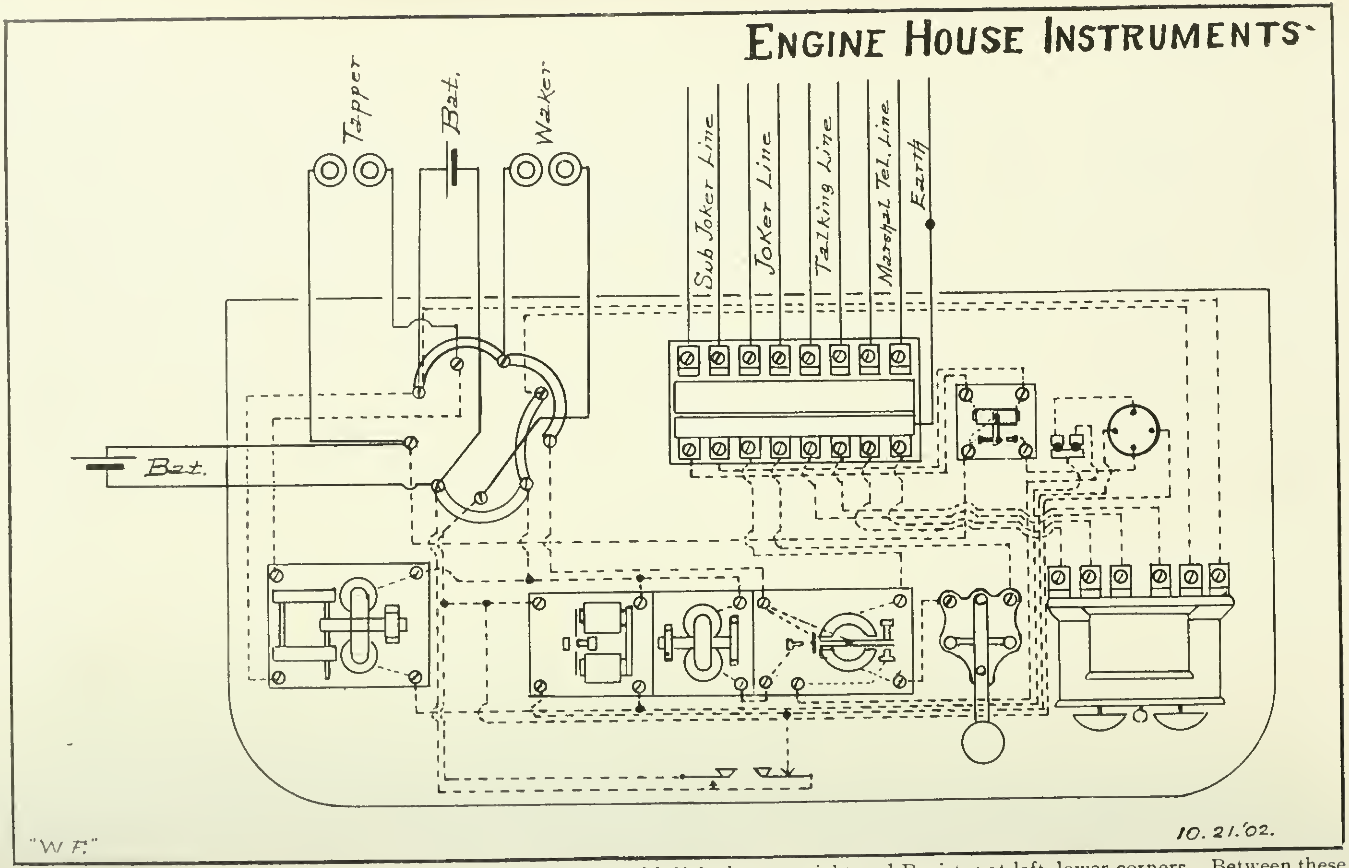


Fig. 15.—Diagram showing complete Engine House equipment, with Telephone at right and Register at left, lower corners. Between these are the Telegraph Key, Polarizing Relay, Sounder and Table Relay. Above these, at the right of line connections, is another polarizer.

are only polarized relays. This prints two records of the box in each engine house. Immediately following it is repeated on the key controlling the pole changers in the sub- or secondary alarm lines, and two more records of the box are printed in a like manner, and if the attendant at each engine house is not at his post to hold out of service the large gong it will sound and awaken the men. It will therefore appear that the attendant must be at his post of duty and is sure to be caught if asleep when an alarm comes in and to which his company does not respond.

It would seem from this description that the operation of such a system would be slow, and valuable time might be lost, but actual records of alarms received and transmitted show the average time required to receive an alarm from the box and transmit it over the two lines as described, requires but twenty-four and one-half seconds, and with short number boxes has been less than fifteen seconds. This speed cannot be obtained with any automatic repeating or transmitting device in service at the present time, and it is doubtful if such apparatus will ever reach the state of perfection that will permit it to equal these records.

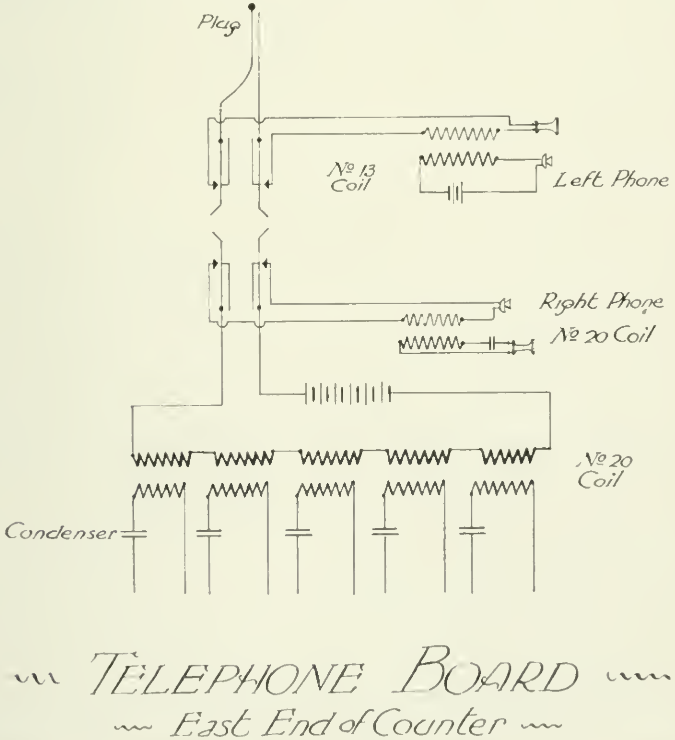


Fig. 16.—Diagram showing manner of repeating messages simultaneously over 5 different lines.

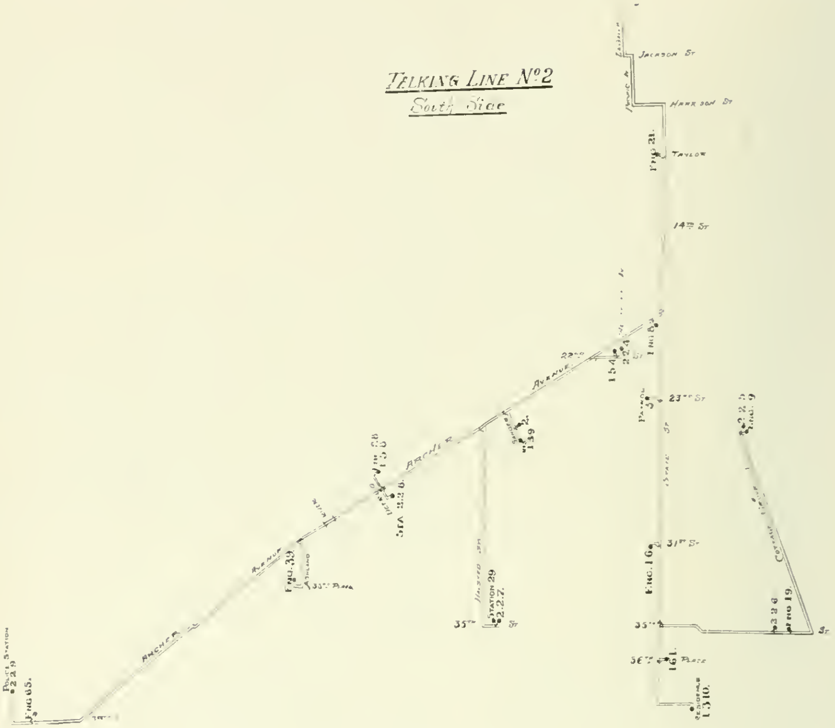


Fig. 17.—Diagram showing telephone line to different Engine Houses in one of nine districts.

To keep such a system as this in perfect operating condition requires a force of men who are highly intelligent and can be relied upon to give their best efforts to the work. Trouble must be anticipated, not awaited, and careful inspections must be made constantly. When it is considered that the apparatus is distributed in nearly one hundred and fifty locations within an area of 180 square miles, and that three different circuits of wire must be maintained between each group of engine houses and the central offices, involving the maintenance of over 5,000 miles of wire, some idea is conveyed of the magnitude of a system in a large city.

The receiving and transmitting of alarms is not all that is required of a modern fire alarm system. There are special orders to be given to the department, such as notification of broken bridges, impassable streets, engines out of service, and special duty details. As each company returns from a fire, a report is made to the office by code signals, and then the entire department is notified.

This is accomplished by means of a system of keys in the sub-alarm circuits, magnetically operated, and if information for which there is no code signal is to be transmitted, it is done simultaneously by a system of repeating coils on the telephone lines.

The perfect fire alarm system must be exceedingly rapid in the transmission of alarms, in order that a number of alarms following each other may not cause delay by blocking the system. The system described has the facilities for transmitting sixty complete alarms an hour, repeating each one for comparison, to prevent mistakes, and reporting to the department the time of return to quarters of each engine company that might be engaged at each of the sixty fires. After a recent large fire, at which thirty-one different pieces of fire apparatus and six commanding officers were engaged, the time required to report the companies and officers back to quarters was computed, and it developed that while their returns were distributed over a period of two hours and eighteen minutes, the actual time the circuits were in use was six minutes, divided into thirty-seven different signals, which averaged a fraction less than ten seconds for each.

During the time inventors have been perfecting the ordinary fire alarm system, other inventors have been at work upon automatic means of discovering fires, as well as sending an alarm. Many ingenious appliances have been devised and several have been extensively used. It would require considerable time to describe each one, but the following descriptions of those most commonly used will convey some idea of what has been done in this direction:

### THE MERCURIAL SYSTEM.

This was probably the first system to be extensively used, and in its original construction and design was of little value. It was based on the principle of the ordinary thermometer, though differently constructed. Two wires were run through a certain section of a building, and at intervals of about ten feet were placed the thermostats or circuit closers. This device consisted of a specially shaped thermometer, the ball of mercury being connected to one of the two wires by means of a platinum wire extending through the glass, and the second wire was connected into the glass tube, where the column of mercury, when subjected to sufficient heat, would rise and cause the circuit to be closed, and a current from batteries maintained on the two wires would flow through an annunciator, which indicated the section of the building in which the circuit had been closed. An alarm was also sent to a central office and from there to the fire alarm office, from which latter place the Fire Department received its first notification of an alarm. The principle seemed good and the details of installation, as well as recording and indicating apparatus, were much improved and enlarged upon. It developed in actual practice, however, that the thermostats could not be constructed in such a manner that continual jarring would not affect them, and as they had to be made somewhat delicately, it was difficult to construct a standard thermostat that could be relied upon when subjected to the varying conditions of practical service. As an open circuit was used, no test of the entire wiring could be relied upon, and much of the system might be out of service at a time when it might be called upon to operate by the presence of fire.

This system was subsequently modified and improved by placing in the circuit, sections of metal, fusible at comparatively low temperatures. The presence of high temperatures fused the metal sections subjected to it, and the circuit was opened, thereby actuating certain apparatus designed to indicate the location of the fire. This system has proved of sufficient merit to warrant the insurance companies to adopt their present practice of allowing a certain rebate in insurance rates where such a system is installed and maintained.

The multiphase cable system is similar in operation and in some respects more desirable. The cable is constructed of a number of strands of copper wire wound around a fusible metal wire with a thin braid saturated with an insulating compound of low melting point placed between these two conductors. Around the two is a thin braid, saturated with a compound of low melting point. The two conductors thus form a circuit insulated only by a medium that is ruptured by the application of heat. Excessive heat melts the compound and special metal, thus forming a circuit for the flow of current which actuates the indicating apparatus, similar in form and effect to that of the mercurial system. This system is practically a continuous thermostat, and becomes operative upon the application of excessive heat at any point.

A thermostat constructed with an aluminum diaphragm, adjusted to expand and close or open an electric circuit and thereby actuate indicating apparatus similar to that employed in the other systems, has been tried but not extensively used, although the principle is good and does not possess some faults to be found in other systems.

Another form of thermostat was devised consisting of an expanding metal diaphragm made in the form of a push button and used normally as such. In event of its being subjected to excessive heat, the diaphragm automatically expanded and closed the circuit, causing a continuous ringing of the bells, which were ordinarily operated by pushing the button. As it was impossible to use any particular indicating apparatus with this style of thermostat, it has not been used in actual installation.

No less than twenty different styles of thermostats have been devised in which the breaking of a circuit and the consequent actuating of indicating apparatus was accomplished by the melting of a special fusible metal used to close or hold closed some part of the circuit. In general they have proved unsatisfactory on account of the inability of manufacturers to secure a fusible metal that could be depended upon at all times to fuse at a given temperature.

The principle of the expansion of certain classes of metals when subjected to increase in temperature has been used in the construction of thermostats for automatic fire alarm purposes, but has not as yet proved entirely satisfactory.

Another class of thermostat, in which the circuit is held open by a plug of highly volatile material which, upon application of heat, became easily compressed by the pressure of a spring and thereby closed a circuit, has been tried, but does not meet the requirements, the most important of which is absolute reliability.

With all these different classes of thermostats one has not yet been designed which fully meets the requirements under all conditions. The accompanying illustrations show some of the forms of thermostats alluded to in this description. The diagrams show the general system of wiring with the local indicating instruments common to the systems where thermostats are used.

Probably one of the most ingenious systems ever invented was recently exhibited and under ordinary tests operated satisfactorily. The system comprises a half-inch pipe run through a certain section of a building and terminating in an annunciator of special construction, which, instead of operating by the application of an electric current through a magnet, responded to an increase of air pressure in the pipe. This increase of air pressure was obtained by means of an explosive cartridge inserted in the pipe at frequent intervals. The head of the cartridge was exposed and upon application of a certain temperature exploded and thereby increased the air pressure within the pipe, throwing the drop on the annunciator. The drop on the annunciator not only indicated the section of the building in which the excessive heat existed, but was also arranged to set into operation a transmitting device which terminated in a central station, where a register could be employed to record the alarm. In one instance this transmitting device was connected to a central telephone system and the operator obtained the alarm by the flashing of the signal lamp. No changes were required in the telephone circuit and it was used for commercial business as well as a fire alarm line. Eventually there will be many possibilities for a system of this or similar character in which the telephone lines may be used for the two purposes. The excessive cost of connecting lines will be avoided, likewise the cost of operators, which should bring the total cost of the service down to a point

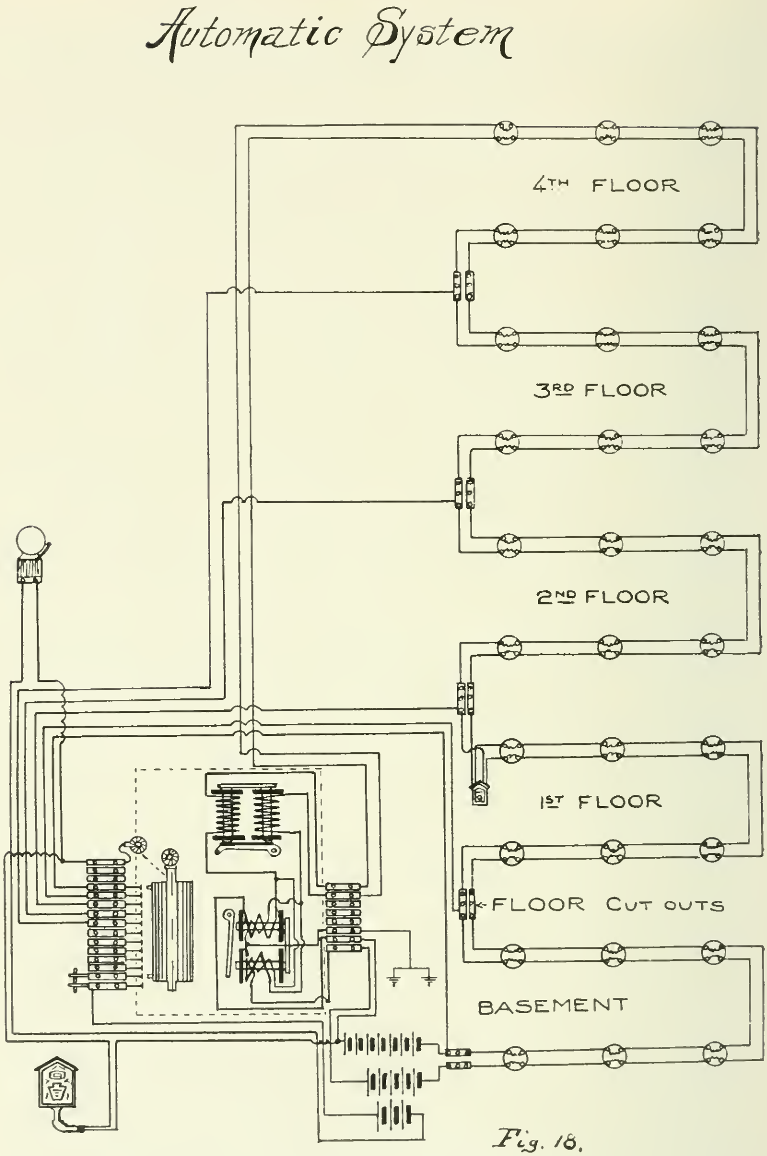


Fig. 18.—Diagram showing connections on one class of Automatic Alarm Systems.

where it will be within the means of small manufacturers and business concerns.

Manual fire alarm boxes connected directly in circuits terminating in the central fire alarm office afford the very best means of re-

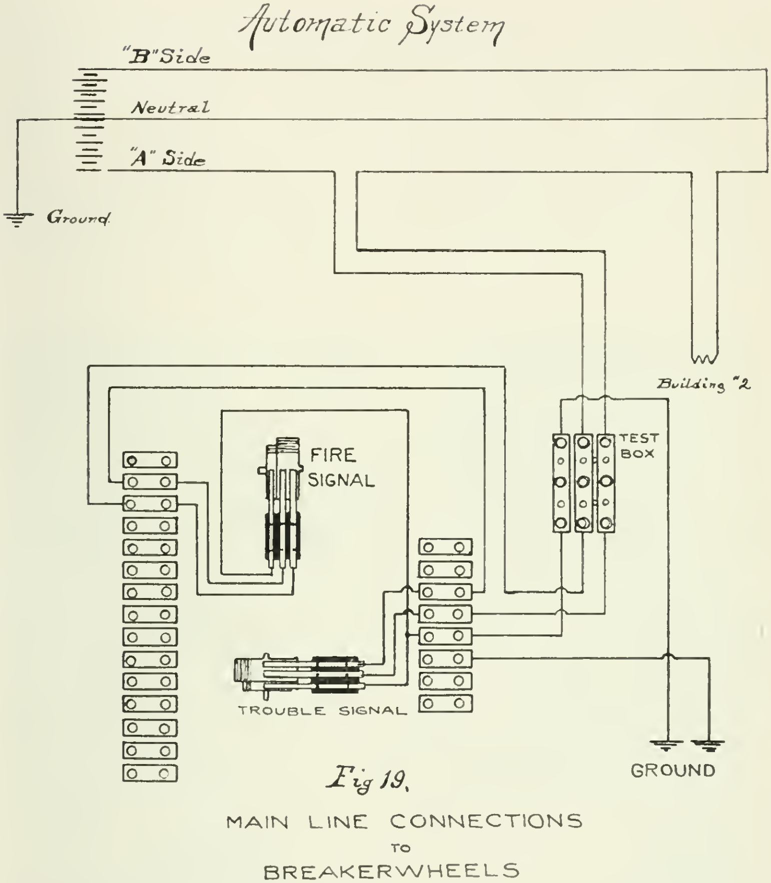


Fig. 19.—Diagram showing connections on another class of Automatic Alarm Systems.

porting fires. The nearest approach to the manual system (which, of course, requires the presence of some one to pull the box) is the connection of some approved automatic system to the fire alarm lines, through a regulation street box, set to automatically operate upon being released by the automatic system. No perfect system of this character has yet been devised, and much work remains to be done before the different city departments will allow such connection to be made to circuits operated by them. Means of testing without sending in a distinct fire alarm, and freedom from false alarms are the two most important features to be eradicated from the existing automatic systems before they can be thorolughly relied upon for connection direct with the fire alarm lines. When some perfect automatic system has been devised and is placed in general use, it will greatly aid the extinguishing of fires in general, and many fires that are now beyond control at time of discovery will be extinguished with a nominal loss. In the words of Fire Marshal Musham, "Any fire can be put out with a pail of water if it is discovered soon enough." It is therefore reasonable to assume that most fires could be well handled with one or two engines if some automatic fire alarm system is perfected whereby an alarm will be sent in before the fire has progressed to a point where a deluge of water would not save anything of value.

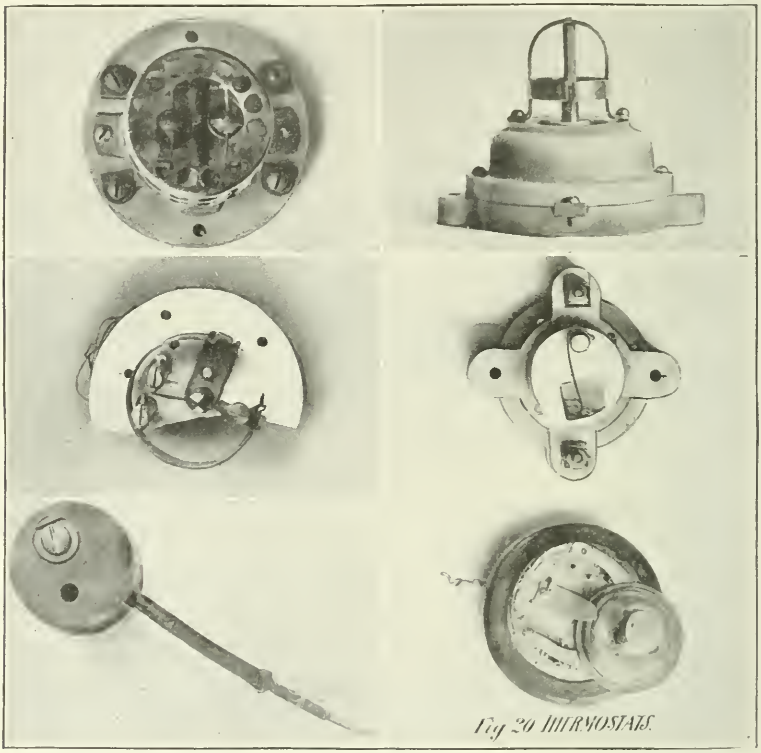


Fig 20 THERMOSTATS.

DISCUSSION.

*Mr. Ellicott*—In preparing this paper I tried to eliminate from it all reference to technical matters and technical terms. I think I have given a pretty fair description of the modern fire alarm system. Of course the different cities have different classes of apparatus for receiving and transmitting their alarms, but they all accomplish about the same result. I am glad that Mr. Page of Joliet has told us what his system would do.

When Mr. Stein, of Australia, was in the city a short time ago he told us what he saw in New York; he said that on investigating their system he found that it took about a minute and a half to send out an alarm. I told him we did considerably better than that; that our records on the 4th of July, when we had a number of alarms, were reduced to an average of 21 seconds for receiving and transmitting each alarm. He said, "that is pretty good, but I can beat that." He then asked me what our best record was. I told him it was a fraction less than 15 seconds. He said he had a record of 13 seconds, so I did not see any chance to get ahead of him. But without trying to minimize the time used in transmitting alarms, I think the tendency is to reduce the actual time in notifying the fire department of the existence of a fire. In this paper there is a short description of the automatic systems that have been used. I do not know of any today that are absolutely successful. There are a great many difficulties to be removed before these systems will give the satisfaction they ought to. We are coming, however, before very long to a system of fire alarm boxes to be placed throughout buildings. That is, in every section of a building will be placed a box connected either to the city system or to a system of its own, The firemen throughout the country are recognizing every year the value of saving a few seconds of time, and all energies are directed toward saving those few seconds.

As Mr. Page has said, the systems in large cities are complicated. Our system is just as simple today as you could possibly devise it, but the magnitude of the system—it being the largest on the face of the earth today, taking in more boxes and delivering the information to more engine houses than any other system that is used—is what makes it appear complicated.

*Mr. E. P. Warner* —I would like to ask, in connection with the system used for communicating with engine houses, the purpose of the transmission of signals by alternating current. I think that the purpose has not been brought out quite so clearly as it might be in the paper, and I would ask Mr. Ellicott to make a brief explanation of this purpose—the reason why the alternating current is used and the purpose served by the arrangement of the polarized relays.

*Mr. Ellicott* That was one of the places where I tried to eliminate all the technicalities possible, and I probably did not make it clear enough.

The real reason for alternating the current, which the pole changer does, is to command the use of the line for two purposes

—that is, sending two different classes of signals over a single line. In sending out a box number, which is the signal for engine companies to respond, the location of the box must be established without reference to any other signal. That could be done in one of two ways; either using the line directly, with the current flowing in one direction, or by reversing the current. The first "Joker" made was just turned around from the present one; that is, the current for transmitting the alarm was the ordinary direct current, but the results secured were not satisfactory, so they adopted the principle of reversing the current in the line. In order to make use of this reversed current, they had to use an instrument that would respond to that reversal and to no other passage of current in the line. Consequently, the polarized relay was introduced. The polarized relay, when the current is ordinarily broken in the circuit, remains stationary, but if the current is reversed in the line, the polarity is reversed—the armature is caused to turn from one side to the other. When it turns to the opposite side it closes a local circuit, in which are recording instruments. Immediately the current is restored to its former direction in the line, the armature of the polarized relay returns to its former position, the indicating apparatus in the local circuit at that time has been actuated, and the register thus operated has made a dot on the paper tape. That is, the current is reversed as many times as you desire to make dots on the paper, and the operation is exactly the same in each instance.

*Mr. Warner*—That is, the primary object of using the current alternating in that way is to permit a double use of the line, so that instead of having to use two lines to give two sets of signals, you use one line, and by means of this alternating apparatus transmit accurately two sets of signals to the various engine houses. Is that right?

*Mr. Ellicott*—Yes, that is right. The other sets of signals we send over this line are sent by a key in the ordinary manner, just as the Morse telegraph code. We use, in some instances, the Morse code. When the repairers on a line are communicating with the office, they use the Morse system, but if we want to send a report out that a company has returned to headquarters, we use the special code. The sending of that signal with the key does not interfere with the polarized relay in any way. It remains dormant.

*Mr. Krum*—That is sent with the direct current, is it not?

*Mr. Ellicott*—Yes, the direct current circuit is opened and closed. The alternating current brings into action the polarized relay in which the recording apparatus is regarded on its local points.

*Mr. Warner*—I notice that Mr. Ellicott, in describing the lines as they enter the station, mentions them as passing through safety appliances. That would indicate that there were many things in connection with the system that placed the system in jeopardy to some extent. I would like to hear from Mr. Ellicott as to these safety devices, their application and the success obtained.

*Mr. Ellicott*—Here in Chicago we have tried no less than four different devices for protecting the office instruments from crosses with high tension trolley lines and lightning discharges, but we have not been able to find anything that could be relied upon to operate quick enough. We finally devised a circuit-breaker which works magnetically, and which, up to the present time, has not failed in a single instance. It is not complicated. We had a cross last Friday with the West Division Street Railway, and it operated perfectly. We also had a cross two or three days before that with the Commonwealth Electric Company (3,000 volts), and saved our instruments in the office and kept the line open, showing the cross was still on until a repairer reached the point. We have tried safety devices in other places, but the discharge of lightning is liable to burn out the safety devices and leave the circuit open.

There was one storm in 1898, when a number of wires were broken down across trolley wires, and in one hour the damage done to our system cost us $2,200 to repair. Besides, it was quite a serious matter. There were a number of lines out of service, in addition to the amount of money expended.

*Mr. Warner*—I would like to ask whether there is any one device that has been found capable of giving complete protection?

*Mr. Ellicott*—We have two different devices; the circuit-breaker, which opens the circuit on the presence of an excess of current on a line, and ordinary lightning arresters. These are the only two devices we use at the present time, for the protection of the instruments on a line during these crosses and lightning storms.

*Mr. Warner*—Do you think the instruments would be jeopardized very often?

*Mr. Ellicott*—The apparatus in all the fire alarm boxes is automatically shunted. It is not in the circuit and cannot be in the circuit except when the box is pulled. Of course when the box is sending in the alarm it must be in the circuit. Normally it must be out of the circuit, so there is no danger to the boxes from crosses on a line except if one happened to be pulled at the time the cross existed.

*Mr. Hatch*—Where a line is out of use on account of a cross, can you use it at all with the others until it is repaired?

*Mr. Ellicott*—Ordinarily we can remove a cross inside of fifteen minutes after we discover it. We can locate the cross very closely with measuring instruments we have, send the repairer right to that location and he will find it very shortly.

*President Finley*—Where do these repairers make their headquarters?

*Mr. Ellicott*—At the different engine houses.

*President Finley*—Not being in politics, they are always on duty, I suppose.

*Mr. Ellicott*—Our repairers are on duty 24 hours a day. There are 19 men employed to look after fire alarm and police wires. They take care of on an average about 200 miles of wire for each man, and are never off duty a moment without permission direct from the office. Another duty they have is to respond to a great many of the boxes in order to send in second fire alarm or any other information the Fire Marshal desires to transmit to the fire alarm offices. That is not followed out all over the city, but in the central part of the city it is followed very closely.

*Mr. Warner*—As to the matter of interference. It used to be the custom to supply all circuits with non-interfering boxes and lay a great deal of stress on that particular feature, but of late years I have heard some expression to the effect that it was not a good thing, was unnecessary, and that practice had proved it to be better not to have these devices. I would like to hear from Mr. Ellicott along that line.

*Mr. Ellicott*—The city of Chicago had at one time 200 of the non-interference boxes, but discontinued their use after about one year's trial. I do not know of any place, that is, any large city, where the non-interference box is used. There are a number of complications that enter into the box. Its primary object is that in case two boxes should be pulled at the same time on a circuit, one box would not interfere with the other. We have more boxes here than in any other city, and more fires, and we do not have any trouble with boxes being pulled together on the same circuit. I think it happened once last year that out of over 7,000 alarms we had two boxes pulled at the same time, so that one interfered with the other, but that does not bother our operators at all. They get enough of each of the two boxes to distinguish between them. I know of three boxes being pulled at the same time and the operator got enough of each one of the three to designate them. That is secured partly by the manner in which the three boxes are arranged on the circuits. That is, the consecutive numbers of the boxes that are likely to be pulled together for the same fire, are different, so there is some distinct feature between the numbers. We do not consider the non-interference box as of any particular value.

*Mr. Warder*—Is there any method, Mr. Ellicott, of the Central Office calling back to the box that is being pulled to get them to repeat the call?

*Mr. Ellicott*—No, the signalling apparatus is cut out when the box is in position to be pulled.

*Mr. Warner*—I believe Mr. Ellicott has had a great deal of experience in using the current directly from the generators for operating the lines. I should be very glad to hear as to the amount of success he has had in this line; whether the generators have proved as effective, convenient and reliable as storage batteries in the matter of regulation and general use. Also what he thinks the future practice will be in years to come in that line?

*Mr. Ellicott*—We established our first motor generator sets in 1898. The first set we installed was for six generators and two motors. They were used continually for over a year, and we never shut down except three or four times when we wanted to put in brushes. We were making a test to see how reliable these would prove, and found them reliable enough for use on fire alarm circuits. The current furnished by these generators is practically as steady as we get from storage battery, and in some respects better. The generator also has a little extra capacity to call on, whereas the storage battery has not. I think it will not be many years before they will be used almost exclusively on fire alarm lines, and I prefer them to the storage battery. We have at the present time 19 lines being supplied with current from these motor generators?

*Mr. Warner*—You have individual generators for each circuit?

*Mr. Ellicott*—Yes; of necessity the current must be entirely separate from any other line, or source of supply.

*Mr. Warner*—What can you say as to the arrangement in Joliet, as mentioned by Mr. Page, operating the system from the lighting station? Do you not think that the risk of being shut down sometime would be perhaps too great to allow him to use generators alone? Would it not be necessary to have batteries or something of that kind to fall back on?

*Mr. Ellicott*—I would not want to take the risk. We have two separate sources of current for every line we maintain. We do not even depend on motor generators. If they fail, we can supply current from some other source.

*Mr. Warner*—Do you do that by driving your motor generators by batteries, or using the batteries direct on the line?

*Mr. Ellicott*—By using batteries direct on the line.

*Mr. Warner*—That involves a lot of storage batteries—one for each individual line, so in case your system gives out you can immediately supply the battery service.

*Mr. Ellicott*—You must have some way of furnishing the current to the lines. There are only two ways that you can get it; one by storage batteries, and the other from generators.

*Mr. Warner*—I would like to ask as to the strength of the current you have found best adapted to your circuits?

*Mr. Ellicott*—We are carrying as a maximum 40 mil-amperes. We have some short lines working as low as 32 mil-amperes.

*Mr. Warner*—I presume you maintain the current constant on them by some system of regulation or variation in the voltage of the generators, or by introducing resistance.

*Mr. Ellicott*—We have two means; one of varying the voltage of the generators, and an adjustable resistance in the line. We can adjust to about 20 per cent above and below the normal, which is enough for any variation we ever had in the line.

I would like, Mr. President, to say one thing for the Chicago Fire Department. In a way I am under the Chicago Fire Department; that is, the fire alarm system is really an adjunct of the Fire Department; they practically own it and I merely operate it for them, and all the improvements and changes that are made have to be submitted to them. All the work done during the last five years, during my term of office, has been passed on or approved by either the former chief or the present chief of the department, and the assistance he has given me in the matter has been worth more than my work. I have had the benefit of his years of experience;—what trouble they have had with the apparatus used and the improvements made. Taking these matters into consideration, for what we have in Chicago today, the chief of the department is entitled to as much credit as any one else.

## CLXII.

# THE NEED OF BETTER FACILITIES FOR RESEARCH AND INSTRUCTION IN AGRICULTURAL ENGINEERING.

By Elwood Mead, Department of Agriculture, Washington, D. C.

*Communicated.*

The conditions of farm life and farm labor in the United States have undergone a revolution within the past hundred years. There is no longer an unsettled fertile area to be occupied by our increasing population and to take the place of lands rendered unproductive by erosion or exhausted by wasteful methods of tillage. The remaining unoccupied public lands can only be cultivated at a large preliminary outlay. The primitive life of the frontier is gone and with it has gone the simple life of the farmer, who no longer is satisfied with a mere support, but who now seeks to make his acres yield the largest possible income, and to obtain a constantly increasing reward for his labors. The methods of tillage which followed the burning of forests in the eastern part of the Mississippi Valley, and the early cultivation of the prairie lands in the western part, must now give way to a more scientific cultivation which will preserve the fertility which remains and restore what has been lost. The organization of other industries is compelling the organization of agriculture. The shorter hours and the better conditions of life in factories is having its influence on farm labor. When the worker in the factory has to work only eight hours, the worker on the farm refuses to labor from sunup to sundown as he did in former years. The attractive conditions of city life have acted as a constant drain on farm labor and placed the farmer in direct competition with the manufacturer. In order to meet this competition, the farmer is compelled to give more and more attention to the laying out of his fields in such a way as to economize in the labor of their cultivation, to provide for the removal of water from land where the drainage is too slow, and to prevent destructive erosion where its discharge is too rapid. He must giver greater attention than before to the planning and construction of farm buildings, and he must do as the factories have done—economizing in his outlay by substituting power for hand labor and using the most effective implements and machines.

In providing the latter, American inventive genius and mechanical skill have surpassed the world. The success of American agriculture is largely due to the use of labor-saving devices. It has done more than all other influences combined to cause thought and skill to take the place of muscle and brute strength. So long as men reaped grain with a sickle and threshed it with a flail, there was great need of a strong arm and little need of an alert brain; but the invention of the self-binder exactly reversed those requirements. Strength and endurance became less important than a trained hand and educated mind. The traction engine now hauls a harvester which cuts, threshes, and sacks a hundred acres of grain a day, yet it is controlled by a lever which can be moved by the operator's little finger; but that operator has to be better trained than his predecessor who swung the flail.

The changes in harvesting machinery are typical of the revolution which has gone on in all classes of farm implements. In the place of the crooked stick which served for a plow, and the hoe which acted as a pulverizer, we have complex machines of widely different pattern, on which the operator rides and directs, by means of levers, the mould-boards or revolving disks by which furrows are turned, and the teeth or rollers which mellow the soil for seeding.

The husbandman sowing his grain by hand is now only poetic fiction. He has been displaced by the grain drill. The well-sweep with its oaken bucket has given way to the windmill, and this in place to the pump operated by electricity. In one valley in California water for irrigation is lifted from many wells by means of an electric current generated in the mountain canyons of the Sierras 240 miles away.

For many years our chief cereal, corn, was grown and harvested almost entirely with hand labor. The seed was dropped and covered in this fashion. Now, an ingenious implement, on which the operator rides, plants it either in drills or in checked rows. The man with the hoe has been almost entirely displaced during its growth by the horse cultivator. The corn knife used in its harvesting is as primitive as the sickle of the Egyptian, and no labor on the farm was more exhausting and disagreeable than the cutting and shocking of corn fodder. In recent years, the difficulty of obtaining needed help in this labor, except at a prohibitive cost, has been a serious obstacle in many sections of the West. Stimulated by the demand for an effective substitute, inventors have now devised and created machines by which corn is cut, bound, and shocked by horse power instead of man power, and instead of the husking bee of 50 years ago, we have a complicated machine which, in a single operation, shucks the ear for market, shreds the blades for feed, and splits the stalk for the paper maker. Three men working with comfort and without fatigue perform the disagreeable labors of many men, increase the value of the product, and put to profitable use what was formerly waste material.

Nearly all these changes in the use of machinery have come within the past 50 years, the most startling ones with the past quarter of a century, and there never was a time when this evolution was going on more rapidly than today. The applications of power to farm work is taking new and significant form through the use of steam, gas, electricity and the sun's rays, as substitutes for animal power. The traction engine and the automobile are dividing with the horse the use of country roads. Electricity is beginning to turn wheels on the farm as well as in the factory. The increasing importance of this evolution has attracted the attention of European countries where institutions for the study and improvement of farm machinery, and the education of farmers in its most effective use, are an important feature of agricultural education, and it raises the question whether this country can longer neglect this field of inquiry if we are to maintain our agricultural supremacy.

Interest in these subjects is already so widespread that the agricultural colleges and experiment stations are broadening their work to include courses of study and investigations in agricultural engineering. They find great difficulty, however, in carrying on this work because of the lack of definite information in available form. The need of reliable data has also been made conspicuous by the Irrigation Investigations of the Department of Agriculture. The prosecution of these investigations has required a knowledge of affiliated subjects, the relation of which to irrigation only becomes apparent through a thorough understanding of the situation. Especially is this true of the applications of power to irrigated agriculture. In many places, the most economical and readiest means of securing a water supply is through pumps. Farmers desire to avail themselves of the experience of others before wasting any money in gathering it for themselves; hence, the Department has been called on for information as to the amount of water required to irrigate a given acreage, the size of pump needed to furnish it, and the cost of pumping from different depths; the kind of power to be applied, whether steam, wind, gas, water power, or electricity; the cost of machinery; the expenses of its operation; and, in general, the information which will enable farmers or investors to determine in advance whether or not this aid to agriculture will pay.

The commercial importance of these inquiries can only be understood by those who realize the immense sums of money which are being invested in pumping projects to furnish water. In the rice fields of Louisiana and Texas alone, several hundred thousand dollars are being expended each year. This work is as yet in its experimental stage and the colleges which are equipped to furnish the needed information, and the graduates to install and operate these plants, have before them an important field of influence and service to American agriculture.

There are drops along many irrigation canals which furnish power, which farmers are beginning to utilize. Many inquiries are being received regarding the available horsepower in streams of different falls and different volumes of water, and the best means of transmitting and using this power in the work of the farm. In view of the changes which have taken place in the last quarter of a century, no one can adequately forecast either the extent or direction of this evolution in the future.

There is increasing need of a knowledge of drainage engineering. This does not mean solely a better understanding of how to remove the surplus water from cultivated fields, although this is a question which interests the arid as well as the humid parts of the country, because in all arid lands irrigation has to be supplemented by drainage. The term "drainage" is here used to include, in addition, the drainage of fields, those questions of sanitation and sewage which are now becoming so important in the life of urban and rural communities and in the designing of farm houses and farm buildings. The time is not far distant when, in many parts of the Mississippi Valley, the present practice of draining the sewage of cities into sluggish streams will have to give way to some form of removal and utilization. The growers of high-priced stock must give greater attention to the drainage of barn lots and stables and the kindred problem of ventilation. At present, there is a lamentable lack of definite data and but comparatively few men equipped to give reliable advice.

It is in every way desirable that farm life shall be more attractive and that more attention shall be given to beautifying the environment of rural homes through the artistic laying out of gardens, lawns, and parks. For the performance of this work in the best manner the services of agricultural engineers are required, and we already find, here and there, men who have opened to them careers of usefulness and influence through having given special attention to these subjects. Without doubt, this phase of agricultural engineering is destined to have as important a place in this country as it already occupies in European countries, and it is time that provision is being made for systematic instruction along these lines.

The establishment of courses in agricultural engineering in the agricultural colleges of the country will open up new avenues of employment for farmers' sons who have a liking and aptitude for mechanical pursuits. Over $100,000,000 are now invested in the manufacture of farm machinery and the annual value of the product amounts to a still larger sum. Correspondence and personal intercourse with a large number of manufacturers warrant the statement that the owners of these factories will welcome the graduates of these schools both in their shops and as agents to extend their trade. It is believed that the opportunities for young men along these lines are as great as those which now await the graduates of technical schools in other lines of engineering, while the influence of such training on the improvement of farm machinery and on the economy of its manufacture can not fail to be most beneficial. In the University of Illinois, which has gone farthest in providing a complete course of instruction in this subject, the school of agricultural engineering has grown from an humble beginning, with a barn for a laboratory, to be one of the most important of its industrial schools. It is an attractive course to students, and those from the advanced classes find ready employment during the summer vacations as experts in the erection and running of various classes of farm machinery; nor is the practical value of this education to the future farmer to be disregarded. It supplies the kind of training which every farmer can put to practical use, and of which he will have increasing need in the future.

The establishment of courses of instruction in agricultural engineering in the land grant colleges should be supplemented by systematic research by the U. S. Department of Agriculture. In no other field of agricultural science are there greater opportunities for effective cooperation between the Department and the agricultural colleges and experiment stations. The Office of Experiment Stations is, through its relation to the State stations, greatly interested in this work, and for several years Dr. A. C. True, the director, has done much to call attention to the neglect of this important field. The lack of definite data required to answer the numerous inquiries which come to the Department on matters related to the various branches of farm engineering, and especially those about irrigation, drainage, and the application of power to farm work, has compelled the Office to broaden the scope of its investigations by the addition to its working staff of experts on drainage and agricultural machinery. In addition to the bulletins on irrigation, a report on the evolution of the harvester has been published and reports on other forms of labor-saving machinery are being prepared. That these demands for information and advice will increase with the use of new forms of power and the improvements in types of machines cannot be doubted, and this Office, by acting as a central agency to collect and publish reports on the progress being made in this and other lands, and to cooperate with the colleges and others in laboratory and practical investigations, will do much to promote our agricultural progress.

# THE EXCURSION TO PURDUE UNIVERSITY, LAFAYETTE, IND., OCT. 9TH, 1902.

Engineering Building, Purdue University.

Upon the invitation of the president of the faculty of Purdue University, members and friends of the Society to the number of one hundred and five, including several ladies, made an excursion to Lafayette, Ind., on Thursday, October 9th.

The party started from the Illinois Central Station at 12th street via the Illinois Central and "Big Four" railroads at 9 o'clock A. M. and arrived at Lafayette about 1 P. M., after a comfortable and enjoyable trip.

We were met at the Lafayette station by W. D. Pence, M. W. S. E., Professor of Civil Engineering at Purdue, who escorted us to the electric cars placed at our service by the Lafayette Street Railway Co. for our transfer from the railroad station to the University, about 2 miles distant. Upon arrival at the campus we were welcomed by several members of the faculty and students, who ushered us into the new agricultural building where we did full justice to the excellent and generous lunch provided by our hosts, which was promptly and daintily served by the fair "coeds" of the University.

On account of the delay in our arrival the remarks after lunch were reduced to the minimum and are published herewith. We were then arranged in groups of twenty, more or less, and under guidance of a member of the faculty assisted by a detail from the University military organization, we spent two pleasant and profitable hours visiting the University buildings and points of interest on the campus.

A little before 5 P. M. the electric cars were boarded and we left Purdue with regret that more time was not available to spend there with our pleasant hosts. Leaving Lafayette at 5:11 we reached Chicago before 9 P. M. without any accident or annoyance to mar the pleasures of the day, and feeling that we were under many obligations to the president, faculty and students of Purdue, and to the railroad companies, for a very pleasant and enjoyable outing.

THE ENTERTAINMENT COMMITTEE.

Electrical Building, Purdue University.

## ADDRESS OF WELCOME BY PROF. GOSS, OF PURDUE UNIVERSITY, AT LUNCHEON, OCT. 9TH, 1902.

Mr. President, Members, and Friends of the Western Society of Engineers: It is not expected that any large portion of the brief time which your program permits you to spend upon the grounds of Purdue University will be absorbed by speech making, but a proper recognition of the dignity of the occasion requires that a few words be spoken of welcome and perhaps of explanation.

First of all, I must express to you the disappointment felt by President Stone when he discovered that the date which you had appointed for this visit conflicted with an earlier engagement, in response to which he is today in the city of Atlanta. I can assure you that President Stone has looked forward to your coming with great interest, and previous to his departure found pleasure in arranging for your entertainment.

Purdue's latch string is always out. We are glad to receive the student and to salute the visitor. We are especially pleased to welcome this delegation from Chicago, for Chicago and Purdue are neighbors and Purdue as represented by its foot-ball team contemplates a return visit to Chicago on Saturday.

In preparing for your coming, we have thought it not necessary or desirable to change to any considerable extent the regular order of our work. In following this course, we extend to you the fullest courtesy in our power, for the best thing about Purdue is its routine day by day work, and this we shall endeavor to expose to you. In saying that we have made no departure from the usual program, I must note one exception, evidences of which are here present. I suppose, also, that I need not mention our indebtedness to the young ladies of Purdue, who have been pleased to honor us by their charming presence and efficient service.

Mr. President, your train was late, the time is short, and I must not continue. Permit me, therefore, in behalf of President Stone and the Faculty of Purdue University, to extend to you and to your associates and friends a most hearty welcome.

*President Finley*—Prof. Goss and Members of the Faculty of the Purdue University: In responding to your kind words of welcome, permit me to say that we regret President Stone's unavoidable absence, as it would have given us pleasure to express to him our appreciation of his kind invitation to visit Purdue.

As Prof. Goss has remarked, our time is limited and I shall be brief in what I say. We have had a very delightful trip, and the change from the cloudy, threatening day in Chicago to the bright sunshine of Lafayette permits me to still retain confidence in our efficient Entertainment Committee.

We have been so hospitably received that I wish, on behalf of the Western Society of Engineers, to express our thanks to all who have contributed to our entertainment, especially the young ladies who have served us this delightful luncheon.

I know that rather than listen to me, your guests would prefer to go and see the places where the young men and young women are trained by you to go out into the world to "jostle the older and bolder, and knock out the timid and slim."

*Professor Goss*—There are certain facts concerning Purdue which every visitor should appreciate, and no one is more familiar with them than Professor Pence to whom you are already indebted for many courtesies. I am glad to introduce to you Professor Pence in charge of the department of Civil Engineering.

*Professor Pence*—It is a rare privilege to be the connecting link between an organization like the Western Society of Engineers and an institution like Purdue University. Dean Goss, I suppose, has called on me because I am such a connecting link, and I will make a brief statement concerning the work of Purdue University in the field of technical education.

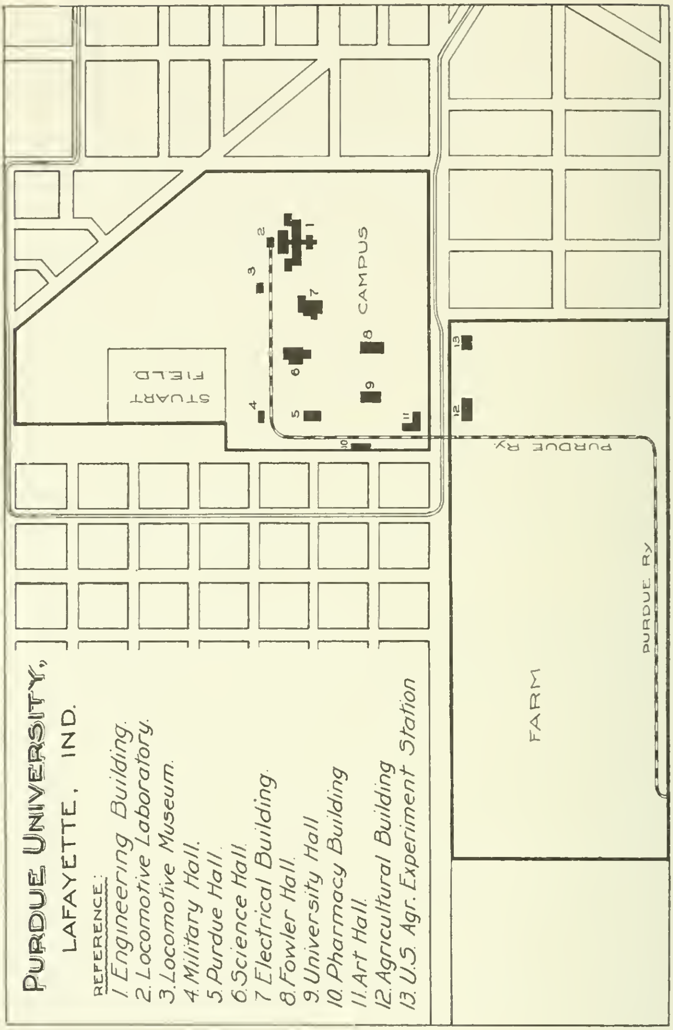
In the state of Indiana there are two state universities, the separation being made between what may be termed the literary courses, on the one hand, and the schools of mechanic arts, on the other. In most of the states where such division is made there is more or less duplication of the engineering courses at the literary school. For example, in the state of Michigan, engineering courses are given both at Lansing and Ann Arbor, and in Iowa at both Ames and Iowa City. In the case of Indiana, however, we have no courses in engineering at the literary institution at Bloomington, so that Purdue University, in a strict sense, is the Indiana Institute of Technology.

Purdue University is the land grant college of the state, having been founded during the sixties under congressional act. It receives support from both the national and state revenues. Its name is derived from John Purdue, who made the initial gift that led to its location at Lafayette.

"It is the purpose of Purdue University to afford to young men and women an opportunity to acquire a good college education in mathematics, science, literature and art, and at the same time to secure ample instruction and practice in such lines of work as will fit them to engage in the practical industries." The curriculum provides abundant work of a cultural nature, it being maintained that breadth of training is as essential to the engineer as to those engaging in the other learned professions.

Six distinct fields or lines of specialization are provided as indicated on the souvenir cards, viz., mechanical engineering, civil engineering, electrical engineering, applied science, agriculture and pharmacy. In each of these departments the instruction is both theoretical and practical. The usual methods of text book study, recitations and lectures are employed, but the student is required to put into practice, as far as possible, the instruction he receives. For example, the mechanical engineer designs, builds, and tests his engines and machines; the electrical engineer his dynamos, etc., and the civil engineering student engages in railway location, the design of bridges, water works, sewerage systems, and so on, with provision, as far as possible, for each branch to get something of the others.

Our time is limited this afternoon, and I will not anticipate the explanations that will doubtless be given to you by your guides. However, I desire to refer very briefly to one or two features which are still in a preliminary stage of development. As most of you know, there has been a strong specialization in the field of Railway Mechanical Engineering at Purdue, under the distinguished leadership of Professor Goss. You will see ample evidences of his activities in your inspections today. The Locomotive Museum, just



started, is an appropriate companion for the Locomotive Laboratory, which "has made Purdue famous."

The very latest project in Railway Engineering at Purdue University is the Track Laboratory and Museum, for which as yet only plans have been made in part. The "Purdue Railway" shown on the card map, is to be transformed into a series of stretches of standard track of the leading railways of the country, exhibiting the various track details, including ballast, ties, rails, joints, etc.

It is proposed to use this track for traffic purposes, hauling fuel, etc., as a means of instruction to students specializing for service in railway maintenance work, for a comparative study of the various kinds of railway track, and for research and experimental work. As far as practicable, it is proposed in time to utilize student labor to maintain the track. The details will be worked out in natural order, and in due time it is hoped to have an exhibit worthy of a careful inspection by those interested in railway track work. In conclusion, I desire to say that when the Western Society of Engineers again visits us, which we trust may be in the near future, we shall hope to have you run your special train in over the Purdue Railway, stopping at Purdue Station on our Campus.

At the conclusion of Professor Pence's address, the party, under the leadership of Mr. Fritz B. Ernst, in charge of Car and Locomotive Design, was divided into five squads, which visited the various laboratories and buildings on the campus, as indicated on the map.

AUGUSTUS TORREY.

IN MEMORIAM.

Since that remote time when the first man laid him down to his eternal sleep on the bosom of mother earth, death has been the common lot of all of human kind; and old as is that fate, and as inevitable, is the grief that comes to the living when one who has been loved and valued puts off the burden of life. Regret we know is useless, but in virtue of the very humanity which entails upon us all the mystic change, we cannot still the heart-throb of sorrow, nor can we bid the tear remain unshed.

Our friend is dead. No ripple from the storm of life can reach him now. For him the concerns of the world have ceased to be. He has passed into the realm of eternal peace.

Ours is the loss — not his; and, as we perform the last sad offices of love and friendship, how much of our grief is assuaged by the thought that the life of our brother was unsullied by a single act unbecoming in a man. It was a life as genial as a summer day; a life rounded out by noble endeavor, by words and deeds of helpfulness to others; and until to each of us comes the dread summons, we shall remember him as he was, bearing on his face the stamp of genuine nobility, and in his heart a love of all that is good and true.

To her who shared with him the sorrows and the joys of life during all the years of their companionship, and to the fatherless in the home that was blessed by his presence, we reach out the hand of genuine sympathy, and mingle with theirs our tears. And as the years shall fall from the present into the past, and the first sharp pang of bereavement is softened by the passage of time, we know that he whom they mourn will lapse into a sweet memory that will remain with them forever.

Mr. Torrey was born at Beverly, Mass., Nov. 21, 1850. A graduate of the University of Vermont, in 1872 he began his professional career on the Burlington and Lamoille Railroad, which is now a part of the Central Vermont system. Serving as division engineer of the road from 1874 until 1876, at the latter date he engaged in hydrauling engineering, prosecuting that branch of his profession in Burlington, Vt., and in a number of towns in Massachusetts. He held the office of superintendent of water works at Burlington, Vt., from 1876 to 1880, when he became assistant engineer of the Michigan Central Railroad, under the late Edward H. Phelps. Mr. Torrey's first work in this capacity was the location and construction of the extension of the old Jackson, Lansing & Saginaw Railroad from Gaylord to Mackinaw.

On the death of Mr. Phelps in 1884, Mr. J. D. Hawks was appointed chief engineer of the Michigan Central and Mr. Torrey became his first assistant. Soon after the resignation of Mr. Hawks, in 1893, Mr. Torrey succeeded to the office of chief engineer, holding that position until his death, on August 20, 1902.

Mr. Torrey was a leading spirit in all movements looking toward track improvement. In this department he experimented with continuous rails in lengths of 100 to 800 feet; he invented a ballast-loading machine and also a form of rail joint which has been used with eminent success. As an author, he published a work on "Switch Layouts and Curve Easements," which is in general use by the profession. He was instrumental in the organization of the Railway Engineering and Maintenance of Way Association, and was one of its first directors. He became a member of the Western Society of Engineers in 1896.

Mr. Torrey was twice married. By his first wife, Miss Lettie E. Durant, with whom he was united in June, 1878, at Montpelier, Vt., he has one child, his daughter Lettie. His second wife was Miss Charlotte Austin Foote, of Detroit, to whom he was married on December 10, 1885, and who, with their three children, Dana Hungerford, Helen C., and Charlotte F., is now living in the old home at Detroit.

C. W. Hotchkiss.
R. W. Hunt.
A. W. Fiero.

Note.—The above portrait cut was courteously loaned by the Engineering News Publishing Co.

# THE TWENTY-FIFTH ANNIVERSARY OF THE ENGINEERS' CLUB OF PHILADELPHIA, DEC. 6, 1902.

An invitation had been extended to the Western Society of Engineers to be represented at this anniversary. President Finley asked Mr. E. Gerber, M. W. S. E., to attend the function as his representative. The dinner was pronounced a grand success. There was an attendance of about 280 out of a membership of about 400—a better showing than is usually had at the annual dinner of the W. S. E.

The dinner was held in the grand dining hall of the Union League Club, and was just about comfortably filled. Many eminent men were present, among which were Gen. Craighill, Admiral Melville, Prof. Coleman Sellers, John Fritz, the iron master, John Birkinbine, the engineer, and other prominent men connected with the industrial world.

Some eleven or twelve toasts were presented, and the speeches were of a high order of merit, and of great interest to those assembled. One speaker attracted particularly the attention of our Mr. Gerber. This was Mr. Chas. F. Scott, president of the American Institute of Electrical Engineers, who addressed the company on "The Engineer of the Twentieth Century." In his remarks he urged coöperation among engineers, and especially of engineering societies, and suggested and affiliation of all engineering socities, and if possible the housing of the national societies (civil mechanical, mining and electrical) in one building and under one roof, but the house should be large enough, that different branches or sections might hold meetings in different rooms at the same hour, and without interference. This idea is worthy of further consideration, with the thought of bringing *all* the engineering societies of the country into closer touch and fellowship. But it should not be urged, if it would lead to a lessening of individual effort and the intercourse between engineers at the local centers. W.

# ABSTRACT OF MINUTES OF THE SOCIETY.

### *REGULAR MEETING, October 1, 1902.*

A regular meeting (No. 479) was held in the Society rooms Oct. 1st, 1902.

The meeting was called to order about 8:15 P. M. with President Finley in the chair, and about 85 members and guests present.

The minutes of the preceding meetings—September 3rd and 17th—were read and accepted.

The Secretary reported, on behalf of the Board of Direction, that at a meeting held September 30th the following applicants were elected into membership:

Geo. C. Geraty, Jonesville, Mich, transfer from Junior to Associate.
P. C. McArdle, Chicago, Active.
John A. Giles, Austin, Ill., Associate.
Arthur J. Mason, Chicago, Active.
Eugene Worthing, Chicago, Associate.
Walter J. Towne, Baraboo, Wis., Active.
H. E. French. Reedsburg, Wis., Active.
John T. Dickerson. Chicago, Junior.
Geo. W. Scott, Chicago, Active.
Otto Schafer, Minneapolis, transfer from Junior to Active.

He also reported that the following new applications had been received:

Allen F. McIntyre, Chicago, Associate.
Robt. C. Smith, Chicago, transfer from Junior to Active.
William Black, Chicago, Active.
Frederick A. Haines, Deadwood, S. Dak., Active.
Geo. W. Jackson, Chicago, Active.

The following proposed amendment to the by-laws of the W. S. E. was read:

"Amend Section 9, Article II, by striking out the words 'by cancelling the names of other candidates, but the number of uncancelled names for each office on the ballot voted must not exceed the number to be elected to such office,' and inserting in their place 'by making a cross opposite the name of each candidate voted for.'" (Signed) B. E. GRANT,
A. V. POWELL,
ANDREWS ALLEN.

and an expression of opinion from the members requested. An explanation was also offered by Mr, Andrews Allen. Little discussion was offered and President Finley said the proposed amendment would go over until the next meeting.

There being no further business, the next in order was the reading of papers, and President Finley introduced Mr. Jas. N. Hatch, who delivered an address on "Modern Handling of Iron Ore on the Great Lakes," which was illustrated by many lantern slides.

Discussion followed the conclusion of his address, by Messrs Finley, Hoover, Tratman, Love, Hatch, and others.

The meeting adjourned at 10 P. M.

### *EXTRA MEETING, October 16, 1902*

An extra meeting (No. 480) of the Society was held October 16th, 1902, in Fullerton Hall of the Art Institute

The meeting was opened at about 8.20 P. M., President Finley presiding and about 175 members and guests present.

President Finley in a few appropriate words introduced Mr Edward Atkinson, president of the Boston Manufacturers Mutual Fire Insurance Company, who addressed the meeting on "Fire Prevention," in which address, by the lantern slides, he showed the gradual evolution of the mill or factory designed to give the least risk of fire and the greatest effective working space and light. A general discussion followed, in which Mr. J. P. Gray—Mr. Atkinson's associate—and Mr. Atkinson replied to the questions.

At the conclusion of the discussion, Mr. C. L. Strobel moved a vote of thanks, on behalf of the Society, to Mr. Atkinson for his very interesting lecture, and also to Mr. Gray.

The meeting adjourned about 10:20 P. M.

### *EXTRA MEETING, October 22, 1902.*

An extra meeting (No. 481) of the Western Society of Engineers, was held October 22nd, 1902.

The meeting was called to order at about 8.15, with President Finley in the chair and about 50 members and guests present.

This being an extra meeting, there was no business to come before the Society.

Mr. J. N. Darling, M. W. S. E., was introduced, who presented a paper on "The Yazoo Delta of Mississippi and Location and Construction of Its Railroads," which was illustrated by many lantern slides. A discussion followed the reading of the paper, by Messrs. Pence, Finley, Wolhaupter, Warder and Darling.

Mr. E. S. Cole, M. W. S. E., was next introduced, who presented a paper on "Water Waste in Cities and Its Detection," which was also illustrated by lantern slides.

Discussion followed from Messrs. Ericson, Finley, Milligan, L. E. Cooley, Burdick, McArdle and Cole.

The meeting adjourned about 10:30 P. M.

### *REGULAR MEETING, NOV. 5, 1902.*

A regular meeting (No. 482) of the Society was called to order about 8:20 P. M. with President Finley in the chair and about 35 members and guests present.

The minutes of the meetings of October 1st, 16th and 22nd were read and accepted.

The Secretary reported, on behalf of the Board of Direction, that at a meeting held November 4th the following applicants were elected into membership:

Allan F. McIntyre, Chicago, Associate.
Robert C. Smith, Chicago, transfer from Junior, Active.
William Black, Chicago, Active.
Frederick A. Haines, Deadwood, So. Dak., Active.
Geo. W. Jackson, Chicago, Active.

He also reported that the following new applications had been received.

F. Seymour Shewell, Hinsdale, Ill., Active.
Maurice M. Willcox, Thebes, Ill., Junior.
Carleton F. Sherman, Carbondale, Ill., Junior.
Henry F. White, Chicago, Active.
Samuel W. McMunn, Chicago, Associate.
Harry Ainsworth, Moline Ill., Associate.
William B. Causey, Joliet, Ill., Active.
Ernest G. Holladay, Carbondale, Ill., Junior.
Otto Gersbach, Chicago, Junior.
Bert Fankboner, Chicago, Junior.
Thomas R. Hasley, Houghton, Mich., Active.
Morgan Brooks, Urbana, Ill., Active.
Louis F. Mahler, Chicago, Active.

Mr. M. K. Trumbull presented the following resolution:

WHEREAS, the Western Society of Engineers lately had an excursion to Purdue University, Lafayette, Indiana; and

WHEREAS, by the courtesy of the President and Faculty of Purdue University, the management of the I. C. R. R., of the C. C. C. & St. L. Ry. and the Lafayette

Street Railway Co., favors were extended to the Western Society of Engineers on this occasion, which contributed greatly to the enjoyment and success of the excursion; therefore be it

RESOLVED, that a vote of thanks of the Western Society of Engineers be returned to the President and Faculty of Purdue University, to the General Managers of the I. C. R. R. and the C. C. C. & St. L. Ry., and to the Superintendent of the Lafayette Street Railway Co.

This was duly seconded and carried

The Secretary presented a resolution prepared by a committee appointed for that purpose after the meeting of September 3rd, 1902, which was as follows:

### RESOLUTION.

That the Western Society of Engineers, having had several meetings in which the Metric System of Weights and Measures and pending legislation pertaining thereto in Congress were duly discussed, and having taken a letter ballot in which 85 per cent of the votes cast were in favor of committing the Society on this subject, the Society now declares that it is in favor of the national adoption of the metric system of weights and measures, and respectfully petitions the Congress to pass House Bill 123, or its equivalent, so as to employ the metric system of weights and measures as proposed in the business of the general government by 1905, and to make it the legal standard for the whole people, but without penalty, in the year 1910

Committee on Resolution.
(Signed) O. CHANUTE.
G. A. M. LILJENCRANTZ.

Per J. H. WARDER, Secretary W. S. E.

At the regular meeting of the Society held October 1st, a proposed amendment to the by-laws was introduced, in regard to the manner of voting, but was laid over until the business meeting to be held November 5th, at which time it was again presented to the Society and announcement was made by the Chair that it would be submitted to the members by letter ballot.

Mr. Andrews Allen introduced the following proposed amendment to the by-laws: "Amend Art. VI., Sec. 7, of the by-laws by inserting after the clause, 'in form prescribed by the Board of Direction,' and if such dues are not paid within ten days from said notice, his name shall be posted on a bulletin board in the rooms of the Society."

(Signed) ANDREWS ALLEN.
JAMES N. HATCH.
MORRIS K. TRUMBULL.

The amendment was discussed as follows:

*Mr. Jas. A. Seddon*—Mr, Chairman, I will say, in regard to this proposed amendment to the by-laws, that I do not think the step would be a wise one. It seems to me that Section 7 of Article VI. of the by-laws should be rigidly carried out, and that this should be sufficient penalty for the non-payment of dues.

Section 7 reads as follows: "Any person whose dues are more than three months in arrears shall be notified by the Secretary. Should the dues not be paid when they become six months in arrears, he shall lose the right to vote or to receive the publications of the Society Should his dues become nine months in arrears, he shall again be notified in form prescribed by the Board of Direction, and if such dues become one year in arrears, he shall forfeit his connection with the Society. The Board of Direction, however may, for cause deemed by it sufficient, extend the time for payment and for the application of these penalties."

*Mr. M. K. Trumbull*—Referring to that portion of the proposed amendment to the by-laws which reads "if such dues are not paid within ten days from said notice," it seems to me that is a little too short a time especially if a member happened to be in a foreign country.

*President Finley*—In a case of that kind of course all due allowance would be made.

*Mr Chas. N. Roberts*—It seems to me that when a member has had nine months in which to pay his dues, ten days notice is long enough

*Mr. E. E. R. Trutman*—Is there anything in the by-laws relating to the expulsion of a member on account of non-payment of dues?

*President Finley*—I think not. A member is dropped unless otherwise acted upon at the discretion of the Board of Direction.

*Mr. Allen*—I have had occasion recently to look into the matter of finances of the Society, and find that there is an amount due the Society, on account of delinquent members, of over $350.00, and it seems to me that some rigid measures should be adopted to secure the collection of these dues. As for myself, I am in favor of posting the names the same as is done by other clubs.

*Mr. B. J. Ashley*—I wish to state that I am not in favor of posting the names of delinquent members. It seems to me it is not a dignified position for the Society, and that if the attention of the delinquent members is called to the fact by letter that their dues are unpaid, it would have the desired effect.

*President Finley*—The Secretary has already done this. Personally I am not in favor of this proposed amendment.

Mr. Seddon suggested that a synopsis of the discussion be sent to all the members by letter ballot, which was covered by a motion from Mr. Chas. N. Roberts, duly seconded and carried.

The Secretary presented, for the consideration of the Society, a letter received from Mr. Richard Price Morgan, M. W. S. E., calling attention to Article II., Section 1. of the Constitution. and offering the following resolution:

WHEREAS, the age, professional education and experience requisite to membership in the Western Society of Engineers establishes a standard of qualifications which has especial value to those who engage the service of its members; and

WHEREAS, this standard, other things being equal, justly entitles members of the Society to suitable and equitable compensation for their services; therefore, be it

RESOLVED, that the President is requested to appoint a committee of five members to investigate and report what compensations less than $1800.00 per annum are made to members of this Society for their services, and what the character of the service is, together with such relevant information as can be obtained, so that the Society will be able to consider the subject intelligently, and if need be promote as much as it may be able the best interests of the profession in respect to compensation for services.

On motion of Mr. Seddon, duly seconded and carried, the Secretary was instructed to place Mr. Morgan's letter on file.

There being no further business before the Society, President Finley introduced Mr. Elwood Mead, Chief of Irrigation Investigations, U. S. Department of Agriculture, who presented a paper on "The Administration of Streams Used in Irrigation," which was illustrated by lantern slides.

Discussion followed from Messrs. Finley, Chas. N. Roberts, Warder, Seddon, Miller, Dart, Julius Stern, Trumbull and Elwood Mead.

Mr. Seddon moved a vote of thanks of the Society to Mr. Mead for his very interesting paper.

The meeting adjourned about 10.40. J. H. WARDER, Secretary.

## *EXTRA MEETING, NOV. 19, 1902.*

An extra meeting (No. 483) of the Society was held Wednesday evening, November 19th, it being called to order by President Finley at 8:10. There were about 85 members and guests present.

This being an extra meeting there was no business to come before the Society.

President Finley introduced Mr. William H. Musham, Chief of the Fire Department of the City of Chicago, who gave a short talk on the Chicago Fire Department. As Mr. Musham's paper on "Fire Extinguishment in Chicago," had been printed and sent out in advance, it was not again read, but numerous lantern slide illustrations were shown, and a short description of each was given by Mr. Musham.

This paper was discussed by President Finley, Messrs. Randolph, Chamberlain, Hatch, Reichmann, and Musham. At the request of President Finley, Fire Marshall Page, of Joliet, gave a little talk on the Joliet Fire Department.

President Finley next introduced Mr. E. B. Ellicott, City Electrician of Chicago, who made a few preliminary remarks with reference to his paper on "The Transmission of Fire Alarms," which paper had also been sent out in advance and was not again read. This paper was discussed by President Finley, Messrs. E. P. Warner (of the Western Electric Co.), Krum, Hatch, Warder and Ellicott.

At the conclusion of this discussion Mr. Modjeski moved a vote of thanks to Chief Musham for his paper on "Fire Extinguishment in Chicago," which motion was duly seconded and carried.

Mr. Isham Randolph moved a vote of thanks to Mr. Ellicott for his paper on "The Transmission of Fire Alarms," which motion was also duly seconded and carried.

The meeting adjourned about 9:45. J. H. Warder, Secretary.

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### *REGULAR MEETING, December 3, 1902.*

A regular meeting (No. 484) of the Society was held December 3rd. The meeting was called to order about 8 15 P. M., with President Finley in the chair and about 75 members and guests present. The minutes of the preceding meetings of November 5th and 19th were read and accepted.

The Secretary presented a report from the Board of Direction, in which the following applicants were reported duly elected into membership:

F. S. Shewell, Hinsdale, Ill., Active.
Maurice M. Wilcox, Thebes, Ill., Junior.
Carleton F. Sherman, Carbondale, Ill., Junior.
Henry F. White, Chicago, Active.
Samuel W. McMunn, Chicago, Associate.
Harry Ainsworth, Moline, Ill., Associate.
Wm. B. Causey, Joliet, Ill., Active.
Ernest G. Holladay, Carbondale Ill., Junior.
Otto Gersbach, Chicago, Ill., Junior.
Bert Fankboner, Chicago, Ill., Junior.
Thomas R. Hasley, Houghton, Mich., Active.
Morgan Brooks, Urbana, Ill., Active.

The following new applications were presented:

Chas. S. Millard, Chicago, Active.
Thos. A. Blenkinsop, Chicago, Active.
Victor Hommel, Chicago, Junior.
Frank L. Batchelder, Houghton, Mich., Active.
Julius Stern, Chicago, Associate.
Chas. F. Berger, Chicago, Associate.
Paul L. Wolfel, Pencoyd, Pa., Active.
J. E. Grady, Chicago, transfer from Junior to Active.
Willard G. Carlton, Chicago. Active.

The Secretary announced the result of the letter ballot on certain amendments to the by-laws,

The amendment of Art. II, Sec. 9, providing for the method of marking the ballots in voting for officers of the Society, making use of a cross (X) opposite the candidates voted for,—affirmative, 87; negative, 6. Carried.

The amendment of Art. VI, Sec. 7, as to posting in the rooms of the Society the names of members delinquent in their dues: Affirmative, 11; negative, 87. Lost.

The Secretary also announced the result of the canvass of nominations for the officers for 1903 as follows:

President, Ralph Modjeski.
1st Vice President, H. W. Parkhurst,
T. W. Snow.
2nd Vice President, F. E. Turneaure,
H. W. Parkhurst.
Treasurer, Andrews Allen.
Trustee, B. E. Grant.
W. M Hughes

This business having been disposed of, Mr. J. F. Jackson, M. W. S. E., Houghton, Mich., was introduced by the President. He addressed the Society on "Copper Mining in Upper Michigan." The address was illustrated by some lantern slides, some large diagrams, and a number of photographs, besides samples of ore, mineral rock and copper.

Discussion followed from President Finley and Messrs. W. E. Williams, Morehouse, H. R. Abbott, Wolfel, Reichmann, Andrews Allen, and J. F. Jackson.

The meeting adjourned about 10 P. M.

### *EXTRA MEETING, December 10, 1902.*

An extra meeting (No. 485) was held on the evening of December 10th, and was called to order by President Finley at about 8.20. There were about 80 members and guests present.

As there was a little delay in the arrival of Capt. Jaques, and as the Secretary had prepared a diagram for the purpose of illustration, he gave a short talk on the organization of the Allis-Chalmers Company, showing by aid of the diagram the responsibilities and limitations of the several departments, and the heads of the same, with their subdivisions, their interrelation, etc.

Gen. Wm. Sooy Smith also gave a few minutes talk on his recent trip to Japan, Korea and China, and the result of some of his observations there.

Capt. W. H. Jaques was then introduced by President Finley. He gave a lecture, illustrated by a great number of lantern slides, on "Submarine Navigation and Warfare." Some discussion followed from Messrs. W. E. Williams, L. E. Cooley, Julius Stern, Finley, Morehouse and H. R. Abbott.

In conclusion Mr. Strobel moved a vote of thanks to Capt. Jaques for his lecture, which was duly carried and the meeting adjourned about 10 P. M.

### *EXTRA MEETING, December 17, 1902.*

An extra meeting (No. 486) of the Society was held December 17th. The meeting was called to order about 8:20 P. M. by President Finley, with about 55 members and guests present. No business was brought before the meeting.

The Secretary read the paper for the evening, "Diversity of Practice in General Engineering on American Railways," by A. A. Schenck, M. W. S. E., as the author could not be present. Written discussion having been sent in by W. D. Taylor, R. P. Morgan, and H. P. Boardman, these were also read by the Secretary.

Further discussion was contributed by W. E. Williams, W. C. Armstrong, Willard Beahan, and H. J. Slifer.

The hour being late, Messrs. S. M. Rowe and L. E. Cooley deferred their discussion, to be sent in by letter.

The meeting adjourned about 10:30 P. M.

# THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what, for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc.

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

## Rules to Govern the Conduct of this Directory.

**First.** Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

**Second.** When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon, on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

**Third.** Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

**Fourth.** Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of application, and then taken off and destroyed. A brief abstract of each application, identified by number only, and stating character of position sought and salary expected, will be published in the JOURNAL. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

**Fifth.** Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is hoped that this arrangement of applications, etc., filed at the offices of the Society will result in benefit to those members who are seeking a professional engagement.

BY ORDER OF THE BOARD OF DIRECTION.

J. H. WARDER, Secretary.

August 5, 1902.

# ABSTRACT OF APPLICATIONS FOR EMPLOYMENT.

No. 7—Oct. 25, 1902.

*Position Desired.*—Topographical draughting. or general draughting in engineer's office.

*Experience.*—In railroad service as transit man, level man and draughtsman. Seven years experience as draughtsman on canal work. Draughtsman on city surveys, exposition grounds, sewage works, etc. Educated in a military academy.

No. 8—Nov. 6, 1902.

*Position Desired.*—Hydraulic engineering, railroad engineering, or with contracting firm.

*Experience.*—Several years service with a prominent consulting hydraulic engineer, and also with the Sanitary District as assistant engineer. A graduate from course of civil engineering at University of Illinois.

No. 9—Nov. 21, 1902.

*Position Desired.*—Mechanical draughtsman,—preferably on conveying and transmission machinery.

*Experience.*—A graduate from engineering course University of Iowa and have had experience with the Link Belt Machinery Co., Fairbanks, Morse & Co., Borden & Selleck. and the McCormick Harvesting Machine Co.

No. 10—Nov. 21, 1902.

*Position Desired.*—Mechanical, electrical and refrigerating engineer. Design and install power plants, refrigerating plants, etc. Expert tests of boilers, engines and materials of construction.

*Experience*—After completing college courses at Cornell and University of Chicago, was engaged for two years as Professor of Experimental Engineering in a technical school. Have had five years experience in power plants and general enginering work.

No. 11—Dec. 8, 1902.

*Position Desired.*—Engineering or contracting for structural bridge work. Chief engineer or chief draughtsman with manufacturing company preferred.

*Experience.*—Graduate as C. E. in 1889, and since then engaged in the manufacture or contracting for structural steel or bridge work. Had eight years experience in charge of all engineering and contracting for a bridge company.

## LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for August, 1902, we have the pleasure to report the following gifts from donors named:

Department of the Interior, U. S. Geological Survey, pamphlets.
" " " Production of Nickel and Cobalt in 1901, by Pratt.
" " " " " Sulphur and Pyrite in 1901. by Struthers.
" " " " " Asphaltum and Bituminous Rock in 1901. Struthers.
" " " Production of Flint and Feldspar in 1901, by Ries.
" " " " " Salt in 1901, by Struthers.
" " " " " Quicksilver in 1901, by Struthers.
" " " Statistics of the Clay-working Industries in the United States, by Middleton.
" " " Production of Cement in 1901.
" " " Manufacture of Coke in 1901.
" " " Stone Industry in 1901.
" " " Production of Magnesite in 1901, by Struthers.
" " " Occurrence of Strontium Ores in 1901, by Pratt.
" " " Production of Mica in 1901, by Pratt.
" " " Occurrence of Glass-Pot Clays in the United States, by H. Ries.
" " " Production of Zinc in 1901, by Chas. Kirchhoff.
" " " Geology and Mineral Resources, Copper River District, Alaska, 1901.
" " " Reconnaissances in the Cape Nome and Northern Bay Regions, Alaska, in 1900.
" " " Production of Natural Gas in 1901, by H. Oliphant.
" " " " " Phosphate Rock in 1901, by Struthers.
" " " " " Precious Stones in 1901, by Kunz.
" " " Table of Ores of Economic Importance, by E. O. Hovey.
" " " Production of Petroleum in 1901, by F. H. Oliphant.
" " " " " Coal in 1901, by E. W. Parker.
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" " " " " " " 1898 vol. II.

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## BOOK NOTES.

**Steam Heating and Ventilation.** By Wm. S. Monroe, M. E. 6x9 in., cloth; pp. 150. New York, 1902. The Engineering News, Publishers. $2.00.

This short but comprehensive treatise on the subject which its title indicates, has a simplicity of expression and an unaffected manner of stating those facts which long experience has positively demonstrated, as also the conclusions drawn from the author's own experiment and observation, that cannot fail to be both useful and attractive.

The classification of the three general methods of steam heating under the usual terms of "direct," "indirect," and 'direct-indirect," is so clearly set forth that there could be no confusion to the least informed reader

Different forms of radiators are discussed at some length, and the relative values of radiating surfaces under varying conditions, together with the causes of poor circulation, air trapping, consequent water-hammer, and the remedies.

Where exhaust steam is used for heating in large plants, it is clearly shown how, with proper design, there need be but little economical detriment from back pressure on the engine, and it is most pertinently remarked that when only 18½ per cent of exhaust steam can in any case be required to heat the feed water to a boiling point, surely there must be some scientific method to attain economy by utilizing a portion of the remainder.

The latter portion of the book is devoted to the subject of ventilation, both natural and mechanically induced by the use of blowers or exhaust fans or both.

Interesting tables are given, compiled from recent experiment and accepted authorities, as to the air conditions in different classes of buildings, upon which could be determined the necessary capacity of any ventilating system to be satisfactorily efficient.

The author argues strongly in favor of upward ventilation where all exhaust, natural or induced, is above the source of air supply, and he reasons against the practice, of which there are many examples, especially in hospitals, of attempting to draw all vitiated air downward and out through the floor. The latter method is claimed to be unnatural, as it is considered the vitiated air is generally at a higher temperature than the fresh and pure supply.

It can be readily seen, however, that these conditions are subject to any number of variations, due to the general purpose of design and use. T. C. I.

**Stereotomy.** By A. W. French, C. E., and H. C. Ives, C. E. 8vo, pp. 119, 47 illustrations and 22 folding plates, cloth, $2.50. Published by John Wiley & Sons, N. Y., 1902.

This is an elementary text-book on stone cutting by two members of the faculty of the Worcester Polytechnic Institute. The first seventeen pages are devoted to definitions, description of the more common building stones, methods of quarrying, description of tools and surfaces. classification of masonry and specifications. The second chapter of ten pages is devoted to the preparation of drawings, the various methods of cutting stones to form plane and curved surfaces, and an article on models in plaster. The remaining four chapters treat of plane-sided structures, structures containing developable surfaces, the oblique arch and miscellaneous problems.

The book is a desirable addition to the few works which have attempted to treat of the subject of stereotomy. The authors endeavor to do more than make a text-book on mathematical drawing. While the volume is elementary, its value is greatly increased by many references to isolated articles on the same and kindred subjects.

The general character of the print and illustrations will be understood, when it is said that it is a Wiley publication. But two criticisms may be made of the publishers' part of the work : the binding should be such as to permit the volume to lie open and flat, without requiring the use of both hands, and the plates should have been bound separately. G.

**Machinery for Refrigeration.** Being Sundry Observations with Regard to the Principal Appliances Employed in Ice Making and Refrigeration, and upon the Laws Relating to the Expansion and Compression of Gases, Principally from an Australian Standpoint. By Norman Selfe, Member Inst. C. E. Published by H. S. Rich & Co., Chicago. Cloth, 6x9½ in., pp. 372, 213 illustrations. Price, $3.50.

In his introduction the author points out that the commercial production of cold represents one of the marvelous strides made in the nineteenth century in connection with the arts and sciences, and that while the practical evolution of artificial refrigeration hardly dates back 40 years, its present vast proportions have only been obtained within 25 years. The production of ice was the chief aim of the early inventors, but the transportation of food products, and the requirements of industries connected with preservation and cold storage are largely responsible for the remarkable developments of artificial refrigeration in later days.

After a brief historical review and an explanation of the principles involved, the author takes up the questions of the machinery and processes employed. These are of two classes, representing the two main systems in which compressed air and ammonia respectively form the cooling medium. The latter is termed the absorption process. The last named was the first employed. but compression machines are said to now largely outnumber those working on the absorption system. The various machines of different inventors and makers are described in some detail, and profusely illustrated. while the theories and the various stages of the work or processes are also fully described. One chapter is devoted to boilers and another to the ice production per ton of coal. The final chapter, of some 70 pages, is essentially practical and "up to date," describing the latest American machines of various makes. An appendix contains numerous tables of general information, and a list of books, pamphlets and treatises on the subjects included in the book.

**Metallurgical Laboratory Notes.** By Henry M. Howe. 8vo, cloth, pp. XII+140. Published by the Boston Testing Laboratories, Boston, Mass.

This book is designed to be a laboratory guide for students of metallurgy in the technical schools. The laboratory methods for this study, as they are now followed in such institutions, consist in the reproduction of commercial metallurgical operations in miniature, with all the details of manipulation which are necessary in the process when applied on a large scale. The author of this book has arranged a series of laboratory methods for metallurgy which are to illustrate principles chiefly and which are to enable the student to spend more time in thinking than in laborious details of manipulation.

The first group of experiments is intended to offer a short course in metallurgy and cover rather a wide field. There are ten of these experiments. The other experiments outlined in the book are treated systematically, each subject by itself. So, for example, group 2 embraces experiments illustrating pyrometry and calorimetry. Group 3 is a selection of fifteen experiments on the melting-points of silicates. Other groups of experiments are such as relate to refractory materials as used in smelting and furnace works. Another group consists of experiments on iron and steel, and the last group presents the study of other useful metals.

The book, no doubt, will be of much value to the laboratory instructor in metallurgy. L. T.

**City Roads and Pavements Suited to Cities of Moderate Size.** By William Pierson Judson. Cloth, 6x9 inches, pp. 200, illustrated, $2.00. The Engineering News Publishing Co , New York.

This small volume has the merit in a marked degree of conciseness. There is scarcely a sentence in the book that might be profitably omitted. At the same time it contains all the fundamental principles of road building, and is quite up to date. It treats of all modern forms ef pavements, including creosoted wood, rock, asphalt and bituminous macadam, and devotes considerable attention to foundations and the treatment of street-car tracks. While the book does not present any new theories of the science of road building, it is quite in accord with the best practice and can be profitably studied by young engineers.

If the author had devoted a little favorable consideration to granite block pavement as laid in Chicago during the past two years, there would be no occasion to limit the book to cities of moderate size. C. D. H.

**Mechanics' Problems.** Frank B. Sanborn, Prof. of C. E., Tufts College, Mass. Engineering News Pub. Co., N. Y. 5½x8 inches, pp. 156, cloth. Price $1.50.

This new book contains five hundred problems in mechanics, arranged under the respective heads of "Work," "Force," and "Motion." These problems are such as might come in professional practice. A study of the book and solution of the problems would be a valuable discipline. Illustrations are introduced, as was thought desirable, to make the book that more complete. The answers to many cf the problems are printed, and a full index completes the book. But the problems to be solved are the thing, and it is fair to assume that there are a good many engineers who would find some difficulty in taking up these problems at random and solving them offhand without reference to other text-books. The range of these questions and the arrangement under their respective heads is excellent. The book can be confidently recommended to those who desire a little mental stimulus and exercise. It would also be of value to a professor of mechanics in his class work, as furnishing test problems for his students, or as suggestive of others by which to try their progress. W.

# WESTERN SOCIETY OF ENGINEERS

Secretary's Office, Library, Reading Room and Meeting Room
1734-41 Monadnock Block, Chicago

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| First Vice-President | Ralph Modjeski |
| Second Vice-President | Prof. L. P. Breckenridge |
| Treasurer | Andrews Allen |

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| C. W. Hotchkiss | Term expires January, 1904 |
| J. W. Alvord | Term expires January, 1905 |

**The above named officers of the Society constitute its Board of Direction**

Secretary and Librarian
J. H. WARDER

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## MEETINGS

Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

Board of Direction—The Tuesday preceeding the 1st Wednesday of each month.

## NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the Journal.

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Seventeenth List

# Western Society of Engineers

ORGANIZED 1869
INCORPORATED SEPTEMBER 1, 1880

## CONSTITUTION, BY-LAWS, LIST OF OFFICERS AND MEMBERS

JULY, 1902

SECRETARY'S OFFICE, READING ROOM, LIBRARY AND MEETING HALL
NOS. 1734-1741 MONADNOCK BLOCK
CHICAGO

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# WESTERN SOCIETY OF ENGINEERS

## CONSTITUTION

### ARTICLE I.

#### NAME AND LOCATION.

SECTION 1. The name of this Association shall be the Western Society of Engineers.

SEC. 2. The offices of the Society shall be located in the city of Chicago.

### ARTICLE II.

#### OBJECT AND MEANS.

SECTION 1. The object of this Society shall be the advancement of the science of engineering, and the best interests of the profession.

SEC. 2. Among the means to be employed shall be meetings for the reading and discussion of appropriate papers and matters of engineering interest, and for professional and social intercourse; the collection of a library, and the publication of such parts of the transactions as may be deemed expedient.

SEC. 3. The Society shall neither endorse nor recommend any individual or any scientific or engineering production, but the opinion of the Society may be expressed on such subjects as affect the public welfare.

### ARTICLE III.

#### MEMBERSHIP

SECTION 1. The management of this Society shall be in the hands of its Active Members. There may also be connected with the Society, Honorary Members, Juniors and Associates who shall be entitled to all the privileges of the Society, except the right to vote and hold office.

SEC. 2. An Active member shall be a professional Engineer. He shall be at the time of admission to membership at least twenty-five years of age, and shall have been in the active practice of his profession for at least five years; he shall have had responsible charge of work for at least two years. Graduation from a school of Engineering shall be considered equivalent to two years' active practice. The performance of the duties of a Professor of Engineering shall be taken as equivalent to an equal number of years of equal practice.

SEC. 3. An Honorary Member shall be a person of acknowledged eminence in some branch of Engineering, or the sciences related thereto, and who has rendered some special service to the profession.

SEC. 4. A Junior shall be not less than eighteen years of age and a person who is not eligible as an Active Member. He shall have had active practice in some branch of Engineering for at least two years, or he shall have graduated from a school of Engineering of recognized standing.

SEC. 5. An Associate shall be a person interested in the advancement of Engineering knowledge.

## ARTICLE IV.

### OFFICERS

SECTION 1. The officers of the Society shall be a President, a Vice-President, a Second Vice-President, a Secretary, a Treasurer and three Trustees. The President, Vice-President, Second Vice-President, Treasurer and Trustees shall constitute a Board of Direction in which the government of the Society shall be vested.

SEC. 2. Vacancies in any office for the unexpired term shall be filled by the Board of Direction without unnecessary delay.

## ARTICLE V.

### ANNUAL MEETING.

SECTION 1. The Annual Meeting shall be held on the first Tuesday after the first day of January, for the canvassing of the ballot for officers for the ensuing year, the reception of the Annual Reports and the transaction of general business.

## ARTICLE VI.

### AMENDMENTS.

SECTION 1. Proposed amendments to this Constitution must be reduced to writing and signed by not less than ten Active Members, and must be submitted and acted upon as follows:

SEC. 2. Amendments presented to the Secretary on or before the first Wednesday in October, shall be printed and mailed to each member at least fifteen days before the first Wednesday in November. Such amendments shall be in order for discussion at the first regular meeting in November, and may be amended in any manner pertinent to the original amendments by a majority vote at that meeting. They shall then be voted upon by letter ballot, the vote to be counted at the first regular meeting in December.

SEC. 3. An affirmative vote of two-thirds of all ballots cast shall be necessary to the adoption of any amendment. Amendments so adopted shall take effect at the next Annual Meeting.

# BY-LAWS

Amended November 1, 1899.

## ARTICLE I.

### MEETINGS.

SECTION 1. At the Annual Meeting of the Society twenty-five Active Members shall constitute a quorum, and the order of business shall be as follows:

1. Reading of minutes.
2. Report of the Board of Direction.
3. Announcement of the results of election.
4. Address of the retiring President.
5. Address of the President-elect.
6. Adjournment.

SEC. 2. Regular meetings for the transaction of business and the reading and discussion of papers shall be held on the first Wednesday of each month, except January. At these meetings fifteen Active Members shall constitute a quorum.

SEC. 3. The following shall be the order of business at regular meetings:

1. Reading of Minutes.
2. Report of the Board of Direction.
3. Report of standing and special committees.
4. Unfinished business.
5. New business.
6. Reading of papers.
7. Discussion of papers and other questions.
8. Adjournment.

SEC. 4. In addition to the regular meetings, meetings for the reading and discussion of papers shall be held as ordered by the Board of Direction.

SEC. 5. Special meetings may be called by the President, and shall be called on request of ten members, which request shall state the purpose of such meeting. The Secretary shall mail to each member of the Society, not less than one week prior to the date of such meeting, a printed notice which shall state the purpose thereof, and no other business shall be considered at such meeting. At these meetings twenty Active Members shall constitute a quorum.

SEC. 6. Any member shall have the privilege of inviting friends to any meetings of the Society, except special meetings.

SEC. 7. The fiscal year shall commence with the first day of January each year.

## ARTICLE II.

### NOMINATION AND ELECTION OF OFFICERS.

SECTION 1. The President, Vice-President, Second Vice-President and Treasurer shall be elected annually and shall hold their offices for one year and until their successors are elected and qualified. The Trustees shall hold office for three years, one Trustee being elected each year

SEC. 2. The Secretary shall be elected annually by the Board of Direction at a meeting to be held within ten days after the Annual Meeting, or at an adjournment thereof, and shall hold office for one year.

or until his successor is elected, provided that a majority of the entire Board of Direction shall be required to elect the Secretary, this vote to be given if necessary by letter.

Sec. 3. The Secretary shall send to each member of the Society, at least ten days before the Regular December Meeting, a copy of the By-Laws relating to the election of officers, together with any special information that may be required.

Sec. 4. Candidates for each office, except that of Secretary, may be nominated by petitions subscribed to by not less than ten members of the Society. All such petitions must be addressed to the Board of Direction, and be presented at or before the Regular December Meeting. They shall be filed and open to the inspection of members, but they shall not be published.

Sec. 5. All petitions presented shall be canvassed by the Board of Direction, and if it is found that no nomination has been made for one or more officers, the Board shall make the nomination or nominations required to fill out the ticket.

Sec. 6. No member in arrears shall be eligible for office, and the President shall not be immediately eligible for re-election.

Sec. 7. Each nominee shall be promptly notified of his nomination. If any nominee shall be found by the Board of Direction ineligible for the office for which he is nominated, or should a nominee decline the nomination, his name shall not be sent out. The Board of Direction shall make additional nominations when necessary to complete one ticket, up to the time the ballots are sent out.

Sec. 8. At least ten days before the Annual Meeting there shall be sent to each Active Member a letter-ballot with envelopes for voting. This ballot shall contain all nominations made in accordance with this article. The names of nominees for any one office shall be arranged alphabetically without distinguishing marks of any kind.

Sec. 9. Each voter shall indicate his choice for each office by cancelling the names of other candidates, but the number of uncancelled names for each office on the ballot voted, must not exceed the number to be elected to such office. The ballot must then be placed in a blank envelope, sealed and then enclosed in an envelope addressed to the Secretary and endorsed with the voter's signature. Ballots not complying with these provisions shall be rejected.

Sec. 10. The polls shall close at twelve o'clock noon on the day of the Annual Meeting, and the ballot shall be canvassed publicly by three Judges appointed by the President.

Sec. 11. The Secretary shall make, from the signatures on the outer envelopes a list of the voters from whom ballots are received, and shall designate all names and mark all ballots about which there may be any question on account of any rule or By-Law of the Society. A voter may withdraw his ballot and substitute another at any time before the polls close. At the close of the polls, the Secretary shall deliver all ballots received, and the poll list to the Judges of Election. The Secretary shall furnish the Judges an alphabetical list of all Active Members in arrears, and all votes from such Members shall be rejected and returned unopened to the Member voting.

Sec. 12. The Judges shall meet at the rooms of the Society at the time of the closing of the polls. Two Judges shall constitute a quorum. In the absence of a quorum the President shall appoint to fill the vacancies. The Judges shall take the poll list and ballots from the Secretary and proceed forthwith to canvass the same as follows:

1. The ballots shall be checked and all envelopes from members not entitled to vote shall be rejected.
2. The return envelopes shall be removed and destroyed.
3. The ballot envelopes shall be opened and all irregular ballots rejected.
4. The regular ballots shall be counted, and a statement of the votes prepared and signed by the Judges.
5. The report of the Judges shall be handed to the President.

Sec 13. At the Annual Meeting the President shall declare those candidates elected who have received a plurality of the votes cast.

Sec. 14. In case of a tie betwen two or more candidates for the same office, the Annual Meeting shall elect the Officer from among the candidates so tied.

Sec. 15. The Officers-elect shall assume their duties immediately upon receiving notice of their election.

## ARTICLE III.

### DUTIES OF OFFICERS AND COMMITTEES.

Section 1. The President shall have general supervision of the affairs of the Society. He shall preside at meetings of the Society and of the Board of Direction at which he may be present, shall appoint all committees not otherwise provided for, and shall be *ex-officio* member of all committees. He shall, with the Secretary, sign all contracts or other written obligations of the Society which have been approved by the Board of Direction. At the Annual Meeting the President shall present a report containing a statement of the general condition of the Society and an address.

The Vice-Presidents in order of seniority shall preside at meetings in the absence of the President, and discharge his duties in case of a vacancy in the office.

Sec. 2. The Board of Direction shall manage the affairs of the Society in conformity with the laws under which the Society is organized and the provisions of the Constitution and By-Laws. It shall hold stated meetings at least once every month. Special meetings shall be called at the written request of three Dirctors, or upon the order of the President. Three members of the Board shall constitute a quorum.

The Board of Direction shall supervise the investment and care of the funds of the Society; make appropriations for specific purposes; act upon applications for membership as hereafter provided; and generally direct the business of the Society. At least one month before the Annual Meeting it shall appoint an Auditing Committee to consist of three members, no one of whom shall be a Director, whose duty shall be to examine and certify the accounts of the Treasurer and Secretary. It shall cause a record of all its proceedings to be kept and preserved by the Secretary and shall make an annual report at the Annual Meeting, transmitting the report of the Secretary, the Treasurer and of other Officers, and of Committees. It shall fill from the Active Membership of the Society, any vacancy which may occur among the Officers of the Society, but said appointment for such unexpired term shall not render the member appointed ineligible for election at the next Annual Meeting.

It shall have the power to make such rules and regulations, which are not specifically stated in these By-Laws, and which it may deem necessary for the successful management of the affairs of the Society.

Any member of the Board of Direction who shall absent himself from three consecutive and regularly called meetings of the Board without having previously obtained its consent, shall cease to be a member of the Board and the Board shall proceed to fill his place for the unexpired term. Due notice of such action shall be sent to the absent member.

The Board of Direction shall meet within ten days after the Annual Meeting and shall then appoint the following Commitees: A Finance Committee, a Publication Committee and a Library Committee. Each of these Committees shall be composed of three Active Members of the Society at least one of whom shall be a member of the Board of Direction.

The assignments to these Committees shall be such that at least one member of the Finance and Library Committees and two members of the Publication Committee shall have served on the same Committee during the previous year. These Committees shall report to the Board and perform their duties under its supervision.

Sec. 3. The Treasurer shall receive all moneys from the Secretary and deposit the same to the credit of the Society in such depository as may be designated by the Board of Direction. He shall pay all bills when certified as provided by these By-Laws and by rules prescribed by the Board of Direction. He shall keep regular accounts of his receipts and expenditures, which shall be open to the inspection of the Board of Direction at all times. He shall make an Annual Report and such other reports as may be required by the Board. He may be required to give bonds, for the faithful performance of his duties, in such amount and with such sureties as the Board may require. He may receive a salary, the amount of which shall be determined annually for the succeeding year by the Board of Direction at its December meeting.

Sec. 4. The Secretary shall be, under the direction of the President and Board of Direction, the executive officer of the Society. He will be expected to attend all meetings of the Society and of the Board of Direction, prepare the business therefor and duly record the proceedings thereof.

He shall promptly issue notices of meetings, inform committees of their appointment, notify new members of their election and perform such other duties as may be imposed upon him by the Society or Board of Direction.

He shall see that all moneys due the Society are carefully collected, and without loss transferred to the custody of the Treasurer. He shall carefully scrutinize all expenditures, and use his best endeavor to secure economy in the administration of the Society.

He shall personally certify the accuracy of all bills or vouchers on which money is to be paid, and shall countersign the checks drawn by the Treasurer against the funds of the Society, when such drafts are known to him to be proper and duly authorized by the Board of Direction.

He shall conduct the correspondence of the Society and shall keep full record of the same. He shall receive all communications, and after presentation to the Society, or to the proper committee, file such as are not intended for publication.

He shall have charge of the Society's rooms and their contents; shall keep the books, maps and other documents belonging to the Library in such order as to be easily accessible to members; he may establish such rules and regulations, with the advice and consent of the Board of Direction, as may be deemed proper and for the best interests of the Society. He shall keep a correct record of the date of election, resignation or decease of all members and shall annually send to each member of the Society a list of members with their addresses and a record of deceased members, together with a copy of the Constitution and By-Laws.

He shall assist the Publication Committee in preparing the Journal of the Society for publication, and do such clerical and editorial work as it may require of him.

He may receive a salary, the amount of which shall be determined annually for the succeeding year by the Board of Direction at its December meeting.

Sec. 5. The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Society, shall approve all bills before payment, and shall make recommendations to the Board of Direction as to any financial business of the Society.

Sec. 6. The Publication Committee shall have general supervision of the publications of the Society and of contracts and expenditures connected therewith, but all contracts and expenditures shall be subject to the approval of the Board of Direction.

The Publication Committee shall receive and examine all papers offered to the Society. In consideration of papers offered for presentation, those papers containing matter readily found elsewhere, those especially advocating personal interests, those carelessly prepared or controverting established facts, and those purely speculative or foreign to the purpose of the Society, shall be rejected. The committee shall determine which papers shall be read in full, and which shall be printed if read by title only. The committee may return a paper to the writer for correction and emendation, and call to its aid one or more members of special experience relating to the subject treated, either to advise on the paper or to discuss it. Such papers as in the judgment of the committee should appear in the Journal, shall promptly upon their acceptance be printed and distributed to members of all grades; others shall, with the consent of the authors, be suitably indexed and filed for reference, or the committee may make abstracts thereof, which, when approved by the authors, may be published instead of the original papers. Advance copies or abstracts of papers and discussions may be sent to the members before final publication.

Upon the request of the Publication Committee, the President shall appoint not more than five members as special members of the committee to aid in carrying out the duties herein assigned to this committee.

The committee shall, at its discretion, provide for the making and publication of abstracts of papers read before other engineering and scientific societies.

No member of the Society shall, without the consent of the Publication Committee, publish any paper as having been read before the Society, and such permission, when given, shall not be construed as being an endorsement by the Society of any statement of facts or opinions advanced in such papers or publications.

Sec. 7. The Library Committee shall have general supervision of the Library and the Rooms of the Society and the property therein; shall make recommendations to the Board with reference thereto, and shall direct the expenditure for books and other articles of permanent value, of such sums as may be appropriated for these purposes.

## ARTICLE IV.

### ADMISSION TO THE SOCIETY.

SECTION 1. All elections to membership in this Society shall be made by the Board of Direction. Seven (7) affirmative votes shall be required for the election of an Honorary member, and six (6) for the election of an Active member, Associate or Junior, these votes to be cast by letter ballot, if necessary.

SEC. 2. Honorary Members shall be proposed in writing by at least fifteen Active Members, who shall state the reasons for the proposal, and shall certify that the nominee will accept if elected. A person elected as Honorary Member shall be promptly notified by letter of his election. The election shall be cancelled if an acceptance is not received within three months after the mailing of such notice.

SEC. 3. Associate Members shall be proposed in writing by at least five members of the Society, who shall state the reasons for the proposal and shall certify that the nominee will accept if elected.

SEC. 4. An application for admission to the Society as Active Member or Junior, or for transfer from Junior to Active Member, shall embody a concise statement, with dates, of the candidate's professional training and experience; and shall be in a form and in such detail as may be prescribed by the Board of Direction. It shall be signed by the applicant, and shall contain a promise to conform to the requirements of membership, if elected, and shall be accompanied by a deposit of Five Dollars, to be applied on entrance fee if the applicant be elected, or refunded to him if not elected. The application shall be signed by at least three Active Members to whom the applicant is personally known. Applications of Engineers who may be so situated as not to be personally known to three Active Members may be recommended for membership by three members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission.

SEC. 5. All applications shall be presented and read at a regular meeting of the Board of Direction, and if received, shall be placed on file until the succeeding or some subsequent regular meeting, at which time they shall be again read and submitted to a vote.

The names of all applicants received by the Board shall be posted in the rooms of the Society, and sent to each member so as to give opportunity for members to submit objections to any candidates.

SEC. 6. Within one year after the date of the vote, the Board of Direction, upon the receipt of letters from not less than five Active Members in good standing, requesting a reconsideration of the vote on any excluded candidate and stating the reasons for such request, shall consider these reasons, and if the Board deems them sufficient, it shall reconsider the vote upon which the applicant was formerly rejected.

SEC. 7. Each elected candidate shall be duly notified and shall subscribe to the Constitution and By-Laws, and pay his entrance fee and dues. If these provisions are not complied with within three months from the notification of election, such election shall be void unless for special reason the time shall be extended by the Board of Direction. Membership of any person shall date from the date he subscribes to the Constitution and By-Laws and pays his dues.

SEC. 8. A member of any grade in the Society may resign his membership by a written communication to the Secretary, who shall present the same to the Board of Direction at their next meeting; when, if all of his dues shall have been paid, his resignation shall be accepted.

SEC. 9. All persons elected and duly qualified, whose address on the records of the Society is within fifty miles of the post office in the city of Chicago, shall be deemed resident; and those whose address is beyond that limit shall be deemed non-resident.

The classification of any member for the fiscal year as resident or non-resident, shall be determined by the records of the Society as they may appear on January 1st of that year.

## ARTICLE V.

### DISCIPLINE.

SECTION 1. The Society shall have power to hear and determine upon the conduct of its members for any infraction of its rules and regulations, and for professional misconduct calculated to affect the good name of the Society, or interfere with order and harmony.

SEC. 2. Upon the written request of ten or more Active Members, that for cause therein set forth a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there appears to be sufficient reason, shall advise the accused of the charges against him. He may, if he so desires, present a written defense which shall be considered at a meeting of the Board of Direction, of which he shall receive due notice. Not less than two months after such meeting the Board of Direction shall finally consider the case, and if resignation has not been tendered, or a defense made which is satisfactory to the Board, it shall then notify the person that he will be expelled in one month, unless he elects to appeal from this decision. Appeals will be submitted to the Active Members by letter-ballot in a form to be prescribed by the Board of Direction. The ballot shall be accompanied by a statement of the charges, and the action of the Board thereon, with such information as it deems proper, and also the statement of the person making the appeal. The ballot shall be canvassed by the Board not less than twenty days after its issue. A majority of the ballots cast will be required to sustain the action of the Board. The Board will notify the person and the Active Members of the result of the ballot. In case no appeal be made, the Board of Direction will expel the person, and notify him and the Active Members of its action.

SEC. 3. Any person expelled from this Society shall not be restored thereto.

SEC. 4. No Disciplinary proceedings of the Society shall be given any publicity whatever.

## ARTICLE VI.

### FEES AND DUES.

SECTION 1. An entrance fee of Ten Dollars shall be payable on admission to the Society by an Active Member or Associate, and Three Dollars by a Junior, this sum to be credited against entrance fee at the time of his transfer to another grade. A Junior's connection with this Society shall cease when he becomes thirty years of age, unless he be previously transferred to another grade.

SEC. 2. Honorary Members shall be subject to no entrance fees or dues.

SEC. 3. The annual dues payable by members, whether resident or non-resident, shall be as follows: by Active Members, $7.50; Associates, $7.50; Juniors, $5.00, of which dues $2.00 shall be set aside as subscription to the Journal.

Sec. 4. In addition to the dues prescribed in the preceding section, Resident Members shall pay annually as follows: Active Members, $2.50; Associates, $2.50.

Sec. 5. The annual dues shall be payable in advance and shall become due on the 15th day of January for the ensuing year. It shall be the duty of the Secretary to notify each member of the amount due for the ensuing year within three days after the Annual Meeting.

Sec. 6. Persons elected to any grade of membership in the Society after the first two (2) months of any fiscal year have expired, shall pay only such amount of dues for that fiscal year as is proportional to the part of the year remaining. For the purpose of reckoning the proportional amount of dues to be paid, the year shall be divided into six periods of two months each.

Sec. 7. Any person whose dues are more than three months in arrears shall be notified by the Secretary. Should the dues not be paid when they become six months in arrears, he shall lose the right to vote or to receive the publications of the Society. Should his dues become nine months in arrears, he shall again be notified in form prescribed by the Board of Direction, and if such dues become one year in arrears, he shall forfeit his connection with the Society. The Board of Direction, however, may for cause deemed by it sufficient, extend the time for payment and for the application of these penalties.

Sec. 8. The Board of Direction may, for sufficient cause, temporarily excuse from payment of annual dues any member who from ill-health, advanced age, or other good reason assigned, is unable to pay such dues; and the Board may remit the whole or part of dues in arrears, or accept, in lieu thereof, desirable additions to the Library, or collections.

Sec. 9. Every person admitted to the Society shall be considered as belonging thereto and liable for the payment of all dues until he shall have resigned, been expelled, or have been relieved therefrom by the Board of Direction.

## ARTICLE VII.

### MISCELLANEOUS.

Section 1. In all questions involving parliamentary rules "Robert's Rules of Order" shall be the governing authority.

Sec. 2. Members of this Society of every grade who shall have been such for at least one year and have complied with the provisions of the Constitution and By-Laws shall be entitled to a diploma, certifying the grade of membership, which shall be signed by the President and attested by the Secretary under the seal of the Society.

Sec. 3. The following are hereby declared to be the authorized abbreviations to be used by the members of the Society having occasion to designate themselves as such:

| | |
|---|---|
| For Active Members | M. W. S. E. |
| " Honorary Members | Hon. M. W. S. E. |
| " Juniors | Jun. M. W. S. E. |
| " Associate Members | Assoc. M. W. S. E. |

## ARTICLE VIII.

### AMENDMENTS.

SECTION 1. Proposed amendments to these By-Laws must be reduced to writing, signed by at least three Active Members, and presented at a regular meeting of the Society. They may then be amended by a majority vote of the meeting. They shall then be submitted to a vote by letter-ballot, the vote to be counted at the next regular meeting. An affirmative vote of two-thirds of all ballots cast shall be necessary to the adoption of an amendment. Amendments so adopted shall take effect immediately.

# WESTERN SOCIETY OF ENGINEERS

Secretary's Office, Reading Room and Library and Meeting Hall.
1734-41 Monadnock Block.

## LIST OF OFFICERS FOR 1902.

*President*
William H. Finley

*First Vice-President*
Ralph Modjeski

*Second Vice-President*
L. P. Breckenridge

*Treasurer*
Andrews Allen

## TRUSTEES

*Term expires January, 1903*
Bion J. Arnold

*Term expires January, 1904*
Chas. W. Hotchkiss

*Term expires January, 1905*
John W. Alvord

The above named officers of the Society constitute its Board of Direction.

*Secretary and Librarian*
J. H. Warder

## MEETINGS

*Annual Meeting:* Tuesday after the 1st day of January
*Regular Meetings:* 1st Wednesday of each month except January
*Special Meetings:* 3rd Wednesday evening of each month
*Board of Direction:* The Tuesday preceding the first Wednesday of each month

# COMMITTEES

## STANDING COMMITTEES

### *On Finance*

Ralph Modjeski, Chairman Andrews Allen D. Royse

### *On Publication*

T. W. Snow, Chairman, 360 Dearborn St.
E. E. R. Tratman, 1636 Monadnock L. P. Breckenridge, Urbana, Ill.

### *On Library*

John W. Alvord Chairman Bion J. Arnold Benj. Wolhaupter

### *On Membership*

Chas. W. Hotchkiss, Chairman C. L. Strobel W. M. Hughes

## SPECIAL COMMITTEES

### *On Entertainment*

William J. Karner, Chairman C. W. Melcher John H. Spengler

# LIST OF MEMBERS*

## HONORARY MEMBER.

(*Hon. M. W. S. E.*)

| NAME | ELECTED |
|---|---|
| MOREHOUSE, L. P., (*Past-Secretary.*)<br>Custodian of Deeds, I. C. R. R.<br>No. 1 Park Row, Chicago, Ill. | M. May 25, 1869<br>Hon. M. Dec. 7, 1887 |

## ACTIVE MEMBERS.

(*M. W. S. E.*)

| NAME | ELECTED |
|---|---|
| Abbott, Arthur V.,<br>Westinghouse, Church, Kerr & Co., 26 Cortlandt St., New York City. | July 3, 1901 |
| Abbott, Herman R.,<br>Asst. Engr., Metropolitan West Side Elevated Railway Co., 1001 Royal Insurance Bldg., Chicago. | Oct. 3, 1894 |
| Abbott, Wm. L.,<br>Chief Operating Engineer, Chicago Edison Co. 139 Adams St., Chicago. | Aug. 10, 1901 |
| Adams, Geo. T.,<br>Civil Engineer and Surveyor, 7120 Princeton Ave., Chicago. | Mar 1, 1898 |
| Adgate, Geo.,<br>Contractor Deep Foundations, 734 Stock Exchange Building, Chicago. | June 18, 1901 |
| Alexander, H. B.,<br>Geneva, Kane Co., Ill. | May 4, 1880 |
| Allan, John B.,<br>Mgr. Engine Sales Dept., Allis-Chalmers Co. 1010 Home Insurance Bldg., Chicago. | Jan 19, 1897 |
| ALLEN, ANDREWS, (*Treasurer.*)<br>Contracting Engineer, Wisconsin Bridge & Iron Company, 1022 Monadnock Block, Chicago. | Mar. 11, 1899 |
| ALVORD, JOHN W., (*Trustee.*)<br>Hydraulic and Sanitary Engineer, 127 Hartford Bldg., Chicago. | Oct. 6, 1885 |
| Ames, Geo. M.,<br>Hauser, Owen & Ames, General Contractors and Civil Engineers, 121 Ottawa St., Grand Rapids, Mich. | Mar. 5, 1895 |

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*Note.—In the interest of all concerned, it is urged upon members to report every change of address promptly to

Secretary,
Western Society of Engineers,
1737 Monadnock Block, Chicago, Ill.

| NAME | ELECTED |
|---|---|
| Amory, E. E.,<br>Engineer and Contractor for Structural Steel. R. 933 No. 108 La Salle St., Chicago. | Nov. 11, 1901 |
| Angier, Walter E.,<br>Resident Engineer, Thebes Bridge, Thebes, Ill. | July 1, 1899 |
| Anthony, F. D.,<br>Chief Engineer in charge of Maintenance of Way, Quebec Southern Ry. Co., Sorel, Que. | Dec. 10, 1897 |
| Armstrong, Wm. C.,<br>Bridge Engineer, C. & N. W. Ry. Co. R. 3 Marine Bldg., Chicago. | May 9, 1901 |
| ARNOLD, BION J., (*Trustee.*)<br>Consulting Electrical Engineer, 1539 Marquette Bldg., Chicago. | Dec. 1, 1896 |
| ARTINGSTALL, SAMUEL G., (*Past President.*)<br>C. E., 13 S. Hamilton Ave., Chicago. | Jan. 2, 1877 |
| Ashmead, Percy Herbert,<br>C. E., American China Development Co. Canton, China. | Dec. 5, 1894 |
| Babo, Alexander von,<br>C. E., Bridge Department, Room 417 City Hall, Chicago. | Apr. 4, 1894 |
| Badt, Francis B.,<br>Consulting Electrical Engineer, 1504 Monadnock Block, Chicago. | Mar. 1, 1898 |
| Bainbridge, Francis H.,<br>Western Expanded Metal & Fire Proofing Co., 414 Claus Spreckles Bldg., San Francisco, Cal. | Nov. 27, 1893 |
| Baker, Ira Osborn,<br>Prof. of Civil Engineering, University of Illinois, Champaign, Ill. | Aug. 3, 1886 |
| Baldwin, Henry F.,<br>Chief Engineer, C. & A. Ry., 919 Monadnock Block, Chicago. | Aug. 6, 1900 |
| Baldwin, Walter H.,<br>Sales Manager, Lidgerwood Mfg. Co., 1510 Old Colony Bldg., Chicago. | Jan. 19, 1897 |
| Barcroft, Frederick T.,<br>C. E., Joy & Barcroft, Architects and Engineers, 407-8 Ferguson Bldg., Detroit, Mich. | May 2, 1900 |
| Barker, Frank W.,<br>Pres. Kenwood Bridge Co., Grand Crossing, Ill. | Feb. 4, 1891 |
| Barrington, Edward,<br>Consulting Engineer and Contractor, Tierra Blanca, State of Veracruz, Mexico. | May 3, 1881 |
| Bates, Lindon W.,<br>Engineer and Contractor, 43 Threadneedle St., London, E. C., Eng. | Oct. 3, 1894 |
| BATES, ONWARD, (*Past-President.*)<br>President Bates & Rogers Construction Co. 1203 Manhattan Bldg., Chicago. | Oct. 24, 1890 |

| NAME | ELECTED |
|---|---|
| Bates, Wm. S., . . . . . . . . . . .<br>Expert in Patent Causes, R. 510 Boyleston Bldg., 269 Dearborn St., Chicago. | Mar. 7, 1901 |
| Bayliss, John Y., . . . . . . . . . .<br>Railroad Work, 4487 Washington Blvd., St. Louis, Mo. | June 24, 1902 |
| Beahan, Willard, . . . . . . . . . .<br>Division Engineer, C. & N. W. Ry. Co. Winona, Minn. | Jan. 7, 1902 |
| Beardsley, James Wallace, . . . . . . .<br>Consulting Engineer Philippine Commission, Manila, P. I. | Dec. 21, 1892 |
| Beckerleg, G. F., . . . . . . . .<br>American Bridge Co., 1315 Monadnock Block, Chicago. | Junior July 1, 1899<br>Active M. Apr. 21, 1902 |
| Beckler, Elbridge H., . . . . . . .. .<br>C. E., Director Winston Bros. Company, 1838 Aldine Ave., Chicago. | Jan. 19, 1897 |
| Bell, Charles H., . . . . . . . . .<br>Buenos Aires, Calle B. Mitre 478 (Escritorio 103), S. A. | Aug. 6, 1896 |
| Bement, A., . . . . . . . . . .<br>Expert in Gas Analysis and Furnace Practice, 218 La Salle St., Chicago. | Mar. 23, 1901 |
| Bergendahl, Gustave Storm, . . . . . . .<br>Squad Foreman, American Bridge Co., 200 Van Buren St., Chicago. | May 13, 1899 |
| Bergquist, John G., . . . . . . . . .<br>Supt. Cement Dept., Illinois Steel Co. South Works. 809 Pullman Bldg., Chicago. | Sept. 16, 1901 |
| Berkeley, R. C., . . . . . . . . . .<br>Contracting Agent, American Bridge Company, 164 Crocker Bldg., San Francisco, Cal. | Feb. 25, 1896 |
| Beye, John C., . . . . . . . . . . .<br>Care Chief Engineer, U. P. R. R., Omaha, Neb. | Mar. 3, 1893 |
| Billin, Charles E., . . . . . . . . .<br>Pres. American Engineering Works, 1545 Marquette Bldg., Chicago. | Jan. 5, 1886 |
| Billow, Clayton O., . . . . . . . . .<br>Mechanical Engineer, 315 Dearborn St., Chicago. | Mar. 17, 1896 |
| Binder, Carl, . . . . . . . . . . .<br>Civil Engineer, Bridges, Structural Iron and Steel Work and Otto aerial wire rope tramways, 901-6 Schiller Bldg., Chicago. | Dec. 1, 1885 |
| Binkley, Geo. Holland, . . . . . . . .<br>Engineer and Manager Railway Dept. Kohler Bros., 1804-12 Fisher Bldg., Chicago. | Sept. 9, 1899 |
| Bley, John Cornelius, . . . . . . .<br>Designer of Bridge Machinery, City Engineer's Office, R. 417 City Hall, Chicago. | Sept. 7, 1895 |

| NAME | ELECTED |
|---|---|
| Blunt, John E.,<br>Consulting Engineer, C. & N. W. Ry. 22 Fifth Ave., Chicago. | June 14, 1869 |
| Boardman, Horace Prentiss,<br>Asst. Engr. Bridge & Bldg. Dept., C., M. & St. P. Ry., Merrill Park Depot, Milwaukee, Wis | Dec. 5, 1894 |
| Boedker, Harold A.,<br>Pres. H. A. Boedker & Co., R. R. Contractors, R. 1208, 355 Dearborn St., Chicago. | July 11, 1894 |
| Bogue, Virgil Gay,<br>C. E., 118 Manhattan Life Bldg., 66 Broadway, New York City. | Dec. 20, 1893 |
| Bowen, H. S.,<br>1121 The Rookery, Chicago. | Apr. 10, 1902 |
| Brace, James H.,<br>Chief Assistant Engineer, Mich.-Lake Superior Power Co., Sault Ste. Marie, Mich. | Dec. 20, 1893 |
| Brainard, C. V.,<br>U. S. Asst. Engr., Illinois River Improvement Co., Kampsville, Ill. | Apr. 2, 1895 |
| Bransfield, James T.,<br>2020 W. 39th St., Chicago. | Apr. 15, 1899 |
| BRECKENRIDGE, LESTER PAIGE, (*2nd Vice-Pres.*)<br>Professor of Mechanical Engineering, University of Ills., Urbana, Ill. | Oct. 28, 1899 |
| Breckenridge, W. L.,<br>Chief Engr., C., B. & Q. Ry., R. 67, 209 Adams St., Chicago. | July 3, 1899 |
| Bremmer, Geo. H.,<br>Div. Engr., C., B. & Q. Ry., R. 67, 209 Adams St. Chicago. | Oct. 4, 1887 |
| Brill, Geo. M.,<br>1134 Marquette Bldg., Chicago. | Oct. 15, 1901 |
| Brinckerhoff, Henry M.,<br>Gen'l Mgr., Metropolitan W. S. Elev. Ry. Co., 1001 Royal Insurance Bldg., Chicago. | Feb. 25, 1896 |
| Brown, Frederick S.,<br>Contractor Bridge Masonry, R. 94, 240 La Salle Street, Chicago. | Apr. 2, 1890 |
| Brown, John Henry,<br>Asst. Engr., Bureau of Sewers, 207 City Hall, Chicago. | July 5, 1893 |
| Brown, J. Melville,<br>Div. Engr., B. C. R. & N. Offices, 1030 Third Ave., Cedar Rapids, Iowa. | Feb. 3, 1892 |
| Brown, Paul G.,<br>Engineer and Supt., 2535 Eastern Ave., Cincinnati, Ohio. | Aug. 6, 1900 |
| Brunner, John,<br>Asst. Gen'l Supt. North Works, Ill. Steel Co., Chicago. | July 8, 1902 |

| NAME | ELECTED |
|---|---|
| Bryant, B. H.,<br>Gen'l Supt., C. M. Ry., Colorado City, Colo. | Nov. 6, 1877 |
| Bull, Storm,<br>Professor of Steam Engineering, University of Wisconsin, Madison, Wis. | Jan. 28, 1899 |
| Burdick, Charles B.,<br>John A. Cole & Son, Consulting Engineers, 1580 Old Colony Bldg., Chicago. | July 13, 1901 |
| Burke, Ricard O'Sullivan,<br>C. E., Harbor Engineer, City Hall, Chicago. | Mar. 6, 1889 |
| Bush, Lincoln,<br>Principal Assistant and Bridge Engineer, D., L. & W. R. R., Hoboken, N. J. | Dec. 30, 1890 |
| Cahill, Walter John,<br>Engr. Lydon & Drews Co., 1322 Chamber of Commerce, Chicago. | Jan. 21, 1901 |
| Caldwell, A. J.,<br>5202 Kimbark Ave., Chicago. | Apr. 26, 1901 |
| Canfield, John Thomas,<br>Metallurgist Fernando Mining Co., San Fernando, Durango, via Tamazala, Mex. | Mar. 21, 1900 |
| Carter, Byron B.,<br>Consulting Mechanical Engineer, 1644 Monadnock Block, Chicago. | Feb. 25, 1896 |
| Carter, Edward C.,<br>Chief Engineer, Chicago & Northwestern Ry., Chicago, Ill. | Sept. 14, 1877 |
| Carter, Henry W.,<br>Patent Attorney and Expert, 1261 Monadnock Block, Chicago. | May 4, 1897 |
| Carter, Richard W.,<br>Missouri Valley Bridge & Iron Works, Leavenworth, Kas. | Apr. 8, 1901 |
| Cartlidge, C. H.,<br>Bridge Engineer, C., B. & Q. R. R., 209 Adams St., Chicago. | Mar. 21, 1900 |
| Caruthers, Wm. S.,<br>C. E., 323 Globe Block, Seattle, Wash. | Jan. 2, 1900 |
| Case, James F.,<br>Asst. U. S. Engr., Improvement, Port of Manila, Santa Lucia Bldg., Malecon Drive, Manila, P. I. | Nov. 5, 1901 |
| Chamberlain, Paul Mellen,<br>Professor Mechanical Engineering, Lewis Institute, Chicago. | Aug. 6, 1900 |
| Chandler, Geo. W.,<br>City Engineer, Canton, Ill. | July 5, 1893 |
| CHANUTE, OCTAVE, *(Past-President)*<br>Consulting Engineer, 413 E. Huron St., Chicago. | July 12, 1869 |
| Chase, Chas. P.,<br>Iowa Engineering Co. and City Engineer, Clinton, Iowa, 411 Weston Block. | Mar. 24, 1897 |

| NAME | ELECTED |
|---|---|
| Childs, Oliver W.,<br>Chief Engineer of Stupp Bros. Bridge & Iron Co., 2301 S. 7th St., St. Louis, Mo. | Mar. 3, 1891 |
| Christie, Geo. B.,<br>Christie, Lowe & Heyworth, Contractors, 171 La Salle St., Chicago. | Jan. 2, 1895 |
| Christie, Wm. M.,<br>Expert Engineering Photographer, 8 So. Peoria St., Chicago. | Junior Mar. 31, 1890<br>Active M. Mar. 21, 1900 |
| Clarkson, Jas. F.,<br>Prendergast & Clarkson, Houghton, Mich. | Mar. 24, 1897 |
| Clausen, G. L.,<br>C. E., Rooms 66 & 67, 164 La Salle St., Chicago. | Oct. 6, 1885 |
| Cole, Edward S.,<br>Mechanical Engineer, John A. Cole & Son, Chicago. | Sept. 2, 1898 |
| Cole, Geo.,<br>Asst. Engr., I. C. R. R., Golconda, Ill. | Mar. 21, 1900 |
| Coleman, James P.,<br>Room 902, 1 Park Row, Chicago. | Mar. 5, 1890 |
| Colton, Simeon C.,<br>Engineer for The Fitz-Simons & Connell Co., 1014 Tacoma Bldg., Chicago. | Mar. 1, 1887 |
| Comstock, Adam,<br>Civil Engineer, 147 S. Hickory St., Joliet, Ill. | July 12, 1869 |
| Comstock, Louis K.,<br>Electrical Engineer, 137 Broadway, New York. | Apr. 30, 1895 |
| Condron, Theodore Lincoln,<br>Consulting Engineer and Representative of the Pittsburgh Testing Laboratory, Ltd., 1750 Monadnock Block, Chicago. | Nov. 7, 1894 |
| Connolly, P. H.,<br>City Engineer, City Hall, Racine, Wis. | Nov. 7, 1894 |
| Cooke, Geo. H.,<br>Asst. Engr. Southern Indiana Ry. Co. Terre Haute, Ind. | Mar. 24, 1897 |
| Cooley, Ernest L.,<br>1010 Security Bldg., Chicago. | Dec. 2, 1891 |
| COOLEY, LYMAN EDGAR, (*Past-President.*)<br>Civil Engineer, 21 Quincy St., Chicago. | June 15, 1875 |
| Copeland, Frederick K.,<br>Pres. Sullivan Machinery Co., 135 Adams St., Chicago. | Oct. 5, 1892 |
| CORTHELL, ELMER LAWRENCE, (*Past-President.*)<br>Civil Engineer, 1 Nassau St., New York. | Feb. 7, 1888 |
| Cox, Arthur J.,<br>Civil Engineer, Iowa Engineering Co., Clinton, Iowa. | Sept. 7, 1897 |
| Cox, James Brady,<br>Chief Engineer, Chicago Junction Ry., 180 Exchange Bldg., U. S. Yards, Chicago. | Oct. 28, 1890 |

| NAME | ELECTED |
|---|---|
| Crabbs, Clarence L., . . . . . . . . . .<br>C. E., 1619, 6th Ave., Moline, Ill. | Jan. 4. 1893 |
| Crissey, John Waterbury, . . . . . . .<br>Asst. Engr., Illinois Central Pass. Depot, New Orleans, La. | Mar. 17. 1896 |
| Cross, Moulton J., . . . . . . . . .<br>Instrumentman, Sanitary District of Chicago, 1008 Security Bldg., Chicago. | Aug. 1, 1894 |
| Curtis, Walter T., . . . . . . . . .<br>Chief Draughtsman, Bridge Dept., C. & N. W. Ry., R. 3, Marine Bldg., Chicago. | June 3, 1902 |
| Curtis, Walter Whaley, . . . . . . . .<br>Consulting Engineer, R. 650, 324 Dearborn St., Chicago. | Dec. 2, 1891 |
| Damon, Geo. A., . . . . . . . .<br>Managing Engineer, Arnold Electric Power Station Co., 1539 Marquette Bldg., Chicago. | Mar. 9, 1901 |
| Darling, Jewitt N., . . . . . . . . . .<br>Asst. Engr. I. C. R. R., 162 Front St., Memphis, Tenn. | Mar. 11, 1901 |
| Darst, John C., . . . . . . . . . . .<br>Darst & Hughes, Contracting Agents, Massillon Bridge Co., 760 Monadnock Block, Chicago. | June 5. 1900 |
| Dart, C. R., . . . . . . . . . . . .<br>Asst. Engr., Sanitary District of Chicago, 1007 Security Bldg., Chicago. | Feb. 3, 1892 |
| Davidson, Frank E., . . . . . . . . . .<br>In Charge Designing and Estimating Dept., Structural Dept., Illinois Steel Co., 50 Wabansia Ave., Chicago. | Jan. 3, 1899 |
| Davidson, George M., . . . . . . . . .<br>Chemist and Engineer of Tests, C. & N. W. Ry., Chicago. | Jan. 11, 1897 |
| Davis, Carl E., . . . . . . . . . . .<br>C. E., Engineer Artesian Water Co., 5th and Auction Sts., Memphis, Tenn. | Sept. 28, 1891 |
| Davis, Charles H., . . . . . . . . . .<br>Consulting Engineer, 25 Broad St., New York City. | Mar. 7, 1900 |
| Davis, Fred., . . . . . . . . . . .<br>Civil Engineer, Newport, Maine. | Aug. 5, 1889 |
| Davis, Garrett. . . . . . . . . . . .<br>Asst. Chief Engr., B., C. R. & N. Ry., Cedar Rapids, Iowa. | May 11, 1892 |
| Dawley, Wm. S., . . . . . . . . . .<br>Chief Engineer, C. & E. I. R. R. Co., 355 Dearborn St, Chicago. | Apr. 2, 1895 |
| Deimling, James F., . . . . . . . . . .<br>Engr. M. of W., L. S. & I. Ry., Marquette, Mich. | May 11, 1892 |
| Delano, Frederic A., . . . . . . . . . .<br>Gen'l Mgr. C., B. & Q. R. R., 209 Adams St., Chicago. | May 24, 1897 |

| NAME | ELECTED |
|---|---|
| Dennis, Wm. F.,<br>Contractor, Rinehart, Dennis & Co., 308 E. Clay St., Richmond, Va. | Dec. 5, 1894 |
| Dike, Chester T.,<br>Resident Engineer, C. & N. W. Ry. Co. Niobrara, Neb. | May 8, 1901 |
| Dobson, Franklin Pierce,<br>Consulting Engineer Railways, Baker City, Oregon. (Box 965 Chicago.) | Nov. 17, 1896 |
| Dosé, Henry Frederick,<br>Div. Engr., Guayaquil & Quito Ry. Co., Guayaquil, Ecuador, S. A. | June 5, 1896 |
| Dougherty, Curtis,<br>Road Master I. C. R. R., 1 Park Row, Chicago. | Apr. 2, 1890 |
| Draper, Henry C.,<br>6606 Perry Ave., Chicago. | Mar. 7, 1882 |
| Dun, James,<br>Chief Engr., A., T. & S. F. Ry. System, R. 1602, Great Northern Bldg., Chicago. | Mar. 17, 1896 |
| Dunbar, James H.,<br>Civil Engr., Matthiessen & Hegeler Zinc Co., La Salle, Ill. | Apr. 7, 1902 |
| Duryea, Edwin, Jr.,<br>Engr. and Supt., Arthur McMullen & Co., Contractors for Substructure, Ohio River Bridge at Mingo Junction, Ohio. | Feb. 3, 1892 |

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|---|---|
| Eldridge, Arch. R.,<br>Bridge Engineer, C., B. & Q. Ry., Chicago. | July 7, 1902 |
| Ellicott, Edward Beach,<br>City Electrician, R. 12, City Hall, Chicago. | Aug. 6, 1900 |
| Elliott, Wm. H.,<br>Signal Engineer, C., M. & St. P. Ry., West Milwaukee, Wis. | June 20, 1900 |
| Elmer, Howard N.,<br>Manager Chicago Office, Trenton Iron Co., 1114 Monadnock Block, Chicago. | Nov. 7, 1894 |
| Enos, Zimri A.,<br>Engineer and Surveyor, 434 N. 2nd St., Springfield, Ill. | Nov. 6, 1878 |
| Ericson, Eric Gustaf,<br>Asst. Engr. Pennsylvania Lines West of Pittsburgh, Pa. | May 4, 1886 |
| Ericson, John,<br>City Engineer, 325 City Hall, Chicago. | May 4, 1886 |
| Ericksen, Eric T.,<br>Supt. of Constr., Bates & Rogers Construction Co., 1203 Manhattan Bldg., Chicago. | Mar. 3, 1891 |
| Eustace, John H.,<br>Engineer People's Gas Light & Coke Co., Michigan Ave. and Adams St., Chicago. | Mar. 1, 1898 |

| NAME | ELECTED |
|---|---|
| Evans, Louis H., Contracting Engineer, No. 7 E. 42nd St., New York City. | Feb. 3, 1892 |
| Evans, Wallace C., Civil Engineer, 100 Y. M. C. A. Bldg., Peoria, Ill. | Jan. 17, 1894 |
| Ewald, Frank G., Consulting Engineer, R. R. & W. Commission, Springfield, Ill. | May 7, 1890 |
| Ewen, John M., 16 Hill St., Finsbury, E. C., London, Eng. | May 7, 1890 |
| Ewing, Wm. Bion, Hydraulic and Sanitary Engineer, 1003 Chamber of Commerce Bldg., Chicago. | Dec. 2, 1891 |
| Ferreira, Chas. E., 7754 Lowe Ave., Chicago. | Jan. 3, 1902 |
| Fiero, Alfred Winfield, Robert W. Hunt & Co., 1121 The Rookery, Chicago. | June 1, 1886 |
| FINLEY, W. H. *(President.)* Prin. Asst. Engr., C. & N. W. Ry., R. 30, No. 22 Fifth Ave., Chicago. | Nov. 7, 1894 |
| Fischer, F. William, Architect and Civil Engineer, 9154 Commercial Ave., Chicago. | Nov. 7, 1889 |
| Fisher, Samuel B., Chief Engineer M. K. & T. Ry., 406 Wainwright Bldg., St. Louis, Mo. | Nov. 11, 1889 |
| FitzSimons, Charles, FitzSimons & Connell Co., 1012 Tacoma Bldg., Chicago. | May 6, 1879 |
| Flather, Frederick A., Supt., McCormick Harvesting Machine Co., Blue Island and Western Ave., Chicago. | Mar. 10, 1902 |
| Foote, Erastus, Pres. Dearborn Foundry Co., 1525 Dearborn St., Chicago. | May 3, 1881 |
| Force, John P., Hydraulic and Sanitary Engineer, 42 Dispatch-Butler Block, Columbus, Ohio. | June 15, 1891 |
| Forsyth, Robert, Consulting Engineer, 1143 The Rookery, Chicago. | Feb. 5, 1878 |
| Foster, Charles F., Consulting Engineer, 1407 Manhattan Bldg., Chicago. | May 5, 1896 |
| Foster, Winslow H., Treasurer Morava Construction Co., 1245 Marquette Bldg., Chicago. | Dec. 5, 1900 |
| Fox, Henry, Locating Engineer, Choctaw, Oklahoma & Gulf R. R., Box 311, Hartshorne, I. T. | Oct. 3, 1900 |

| NAME | ELECTED |
|---|---|
| Franson, Chas. F.,<br>Chief Engineer, James Stewart & Co., Westinghouse Bldg., Pittsburgh, Pa. | Nov. 11, 1889 |
| Frederickson, John H.,<br>Civil Engineer, care James Stewart & Co., Lincoln Trust Bldg., St. Louis, Mo. | Dec. 2, 1901 |
| French, Edgar,<br>Engineer, Detroit Terminal Ry., Lieb & Wight Sts., Detroit, Mich. | Oct. 5, 1892 |
| Friestedt, L. P.,<br>L. P. Friestedt Co., 1200 Tribune Bldg., Chicago. | May 1, 1901 |
| Fulton, John Addison,<br>Civil Engineer, 508 Temple Court Bldg., Chicago. | Jan. 14, 1902 |
| Gaffin, W. W.,<br>Asst. Engr., C. & N. W. Ry., Escanaba, Mich. | Apr. 10, 1902 |
| Gasche, Fred. G.,<br>M. E., Illinois Steel Co., Chicago. | Jan. 2, 1895 |
| Gates, Andrew W., | Apr. 4, 1894 |
| Gates, J. Holt,<br>Elect. Contr. and Prest. Elec. Equipment Co., 939 Monadnock Blk., Chicago. | |
| Gerber, Emil,<br>Asst. to President, American Bridge Co., Pencoyd, Pa. | June 2, 1890 |
| Giaver, J. G.,<br>Chief Engineer, D. H. Burnham & Co., 1142 The Rookery, Chicago. | Nov. 12, 1901 |
| Gibson, Josiah,<br>American Bridge Co., P. O. Box 913, St. Louis, Mo. | Aug. 6, 1900 |
| Giddings, Fred.,<br>City and County Engineer, 921 Kansas Ave., Atchison, Kas. | Feb. 1, 1887 |
| Gifford, Robert L.,<br>Pres. Illinois Engineering Laboratory., 319-20 Manhattan Bldg., Chicago. | Jan. 11,, 1897 |
| Gillingham, Wm. J., Jr.,<br>General Western Agent, The Hall Signal Co., 1423 Monadnock Block, Chicago. | Apr. 5, 1893 |
| Girand, Jas. B.,<br>Girand & Hesse, Prescott, Ariz. | July 9, 1901 |
| Goddard, Leslie Warren,<br>U. S. Assistant Engineer, Grand Rapids, Mich. | Oct. 6, 1886 |
| Goldmark, Henry,<br>Chief Engineer's Office, Canadian Pacific Railway, Montreal, Canada. | Dec. 20, 1893 |
| Gonzenbach, Ernest,<br>Electrical Engineer, The Aurora, Elgin & Chicago Ry., Wheaton, Ill. | June 7, 1902 |

| NAME | ELECTED |
|---|---|
| Goodrich, Harry Clinton,<br>Asst. Engr., R. G. W. Ry., Salina, Utah. | Jan. 3, 1899 |
| Gould, Chas. L.,<br>Treasurer Chicago Crushed Stone Co., 928 Stock Exchange Bldg., Chicago. | Mar. 5, 1895 |
| Graham, William,<br>Asst. Engr., U. P. R. R., Omaha, Neb. | July 11, 1894 |
| Grant, Bertrand E.,<br>Hill & Grant, 935 Marquette Bldg., Chicago. | Nov. 24, 1890 |
| Gray, Elam,<br>With Purdy & Henderson, 1553 Monadnock Block, Chicago. | Mar. 3, 1891 |
| Gray, James C.,<br>Illinois Central R. R. Co., 1 Park Row, Chicago. | June 9, 1902 |
| Green, Oliver B.,<br>403 La Salle Ave., Chicago. | July 12, 1869 |
| Guthrie, Ossian,<br>308 Chamber of Commerce Bldg., Chicago. | Sept. 4, 1889 |
| Hadwen, T. Lovel D.,<br>Asst. Engr. B. & B. Dept., C., M. & St. P. Ry., Marion, Iowa. | May 13, 1899 |
| Hagar, Edward M.,<br>Manager Cement Dept., Illinois Steel Co., 1060 The Rookery, Chicago. | July 30, 1898 |
| Hain, Jas. C.,<br>Engineer Masonry Construction, C., M. & St. P. Ry., 1100 Old Colony Bldg., Chicago. | Apr. 4, 1902 |
| Hall, Chas. S.,<br>Engineer of Track Elevation, C. & N. W. Ry., No. 22 Fifth Ave., Chicago. | May 13, 1901 |
| Harding, James Judson,<br>Asst. Engr., C., M. & St. P. Ry., 1100 Old Colony Bldg., Chicago. | Mar. 7, 1900 |
| Harding, Samuel B.,<br>Pres. and Gen'l Mgr., Modern Steel Structural Co., Waukesha, Wis. | May 14, 1902 |
| Harman, Jacob A.,<br>Civil Engineer, 109 So. Jefferson Ave., Peoria, Ill. | Sept. 26, 1890 |
| Harrison, Charles Lewis,<br>Prin. Asst. Engr., Penn., N. Y. Extension R. R. Co., Astor Court Bldg., New York City. | Dec. 30, 1890 |
| Harvey, Alfred Ernest,<br>Division Engineer, Chicago Great Western Ry., Ft. Dodge, Iowa. | Jan. 3, 1899 |
| Hatch, Frank C.,<br>Vice-Pres. Simons, Hatch & Whitten Co., 32 Otis St., Boston, Mass. | Nov. 7, 1894 |
| Hawkins, Melville S.,<br>Supt. Oliver Iron Mining Co., Mount Iron, Minn. Not a member in 1895, 6, 7, 8, 9. | Mar. 1, 1893 |

| NAME | ELECTED |
|---|---|
| Hawks, Frank W., . . . . . . . . . .<br>Asst. Engr., C. & E. I. R. R., 902 Ellsworth Bldg., Chicago | May 2, 1901 |
| Haynes, Arthur Morton, . . . . . . . .<br>Asst. Eng., U. P. R. R., R. 25, Union Depot, Denver, Colo. | Mar. 7, 1900 |
| Heck, Frank F., . . . . . . . . . .<br>Asst. Engr., C. J. Ry., 180 New Exchange Bldg., U. S. Yards, Chicago. | June 2, 1890 |
| Hedges, Samuel H., . . . . . . . . .<br>Washington Heights, Ill. | Jan. 24, 1901 |
| Heer, Peter, . . . . . . . . . . .<br>Manufacturer of Engineering Instruments, 90 East Ohio St., Chicago. | Jan. 4, 1887 |
| Hegardt, Gustave Bernard, . . . . . . .<br>U. S. Assistant Engineer, Ft. Stevens, Ore. | May 4, 1886 |
| Hegeler, Julius W., . . . . . . . . . .<br>Mathiessen & Hegeler Zinc Co., La Salle, Ill. | Mar. 5, 1890 |
| Heidenreich, E. Lee, . . . . . . . . .<br>Contracting Engineer Monier Constructions and Grain Elevators, 541 The Rookery, Chicago. | May 4, 1886 |
| Heilbronn, E. H., . . . . . . . . . .<br>Sub-Assistant Engineer Sanitary District of Chicago, 1010 Security Bldg., Chicago. | Mar. 7, 1900 |
| Heine, Richard H., . . . . . . . . . .<br>With American Bridge Co., 1772 Deming Place, Chicago. | July 2, 1902 |
| Hellenthal, Karl, . . . . . . . . . .<br>With American Bridge Co., 1436 Osgood St., Chicago. | Mar. 11, 1899 |
| Henderson, Lightner, . . . . . . . .<br>Purdy & Henderson, Civil Engineers, 78 Fifth Ave., New York. | Sept. 28, 1891 |
| Hendricks, V. K., . . . . . . . . . .<br>Asst. Engr., M. of W., B. & O. R. R. Co., Baltimore, Md. | May 7, 1901 |
| Hering, Rudolph, . . . . . . . . .<br>Hydraulic and Sanitary Engineer, 170 Broadway, New York. | June 1, 1886 |
| HERR, HIERO B., *(Past-President.)* . . . .<br>Civil and Mining Engineer, 1246 Marquette Bldg., Chicago. | June 16, 1885 |
| Hill, C. D., . . . . . . . . . . . .<br>Engineer Board of Local Improvements, R. 207, City Hall, Chicago. | Apr. 2, 1890 |
| Hill, Fred L., . . . . . . . . . . . .<br>Hill & Grant, Civil Engineers, 935 Marquette Bldg., Chicago | Oct. 28, 1899 |
| Hillebrand, Gerhard H., . . . . . . . .<br>Chief Draftsman Sanitary District of Chicago, 1005 Security Bldg., Chicago. | Mar. 1, 1898 |

| NAME | ELECTED |
|---|---|
| Hoff, J. H., . . . . . . . . .<br>Contracting Engineer, American Bridge Co., 1315 Monadnock Block, Chicago. | July 1, 1899 |
| Hoffman, Fred., . . . . . . . . .<br>Civil Engineer, Crawfordsville, Ind. | Mar. 11, 1899 |
| Hogan, William F., . . . . . . . . .<br>Street Railway Construction Co., 643 Tenth St., Brooklyn, N. Y. | Apr. 8, 1891 |
| Holmes, Frank, . . . . . . . . .<br>Asst. Engr., care D. H. Burnham & Co., 1142 The Rookery, Chicago. | Jan. 28, 1901 |
| Holthoff, H. C., . . . . . . . . .<br>Vice-Pres. Holthoff Machinery Co., Cudahy, Wis. | May 23, 1902 |
| Honens, Frederick W., . . . . . . . .<br>U. S. Junior Engineer, Illinois and Mississippi Canal., U. S. Engineer Office, Sterling, Ill. | July 1, 1899 |
| Horton, George T., . . . . . . . . .<br>Vice-Pres. Chicago Bridge & Iron Co., Washington Heights Sta., Chicago. | Nov. 7, 1894 |
| HORTON, HORACE E., (*Past-President.*) . . .<br>Pres. Chicago Bridge & Iron Co., Washington Heights Sta., Chicago. | June 7, 1881 |
| Hoskins, Wm., . . . . . . . . . .<br>Mariner & Hoskins, 81 So. Clark St., Chicago. | Sept. 4, 1889 |
| HOTCHKISS, CHAS. W., (*Trustee.*) . . . .<br>Consulting Engineer, 247 Monadnock Block, Chicago. | Jan. 2, 1805 |
| Hotchkiss, W. D., . . . . . . . . .<br>Asst. Civil Engineer, Board of Local Improvements, R. 207, City Hall, Chicago. | June 1, 1886 |
| Howells, Julius M., . . . . . . . . .<br>Consulting Hydraulic Engineer, 401 Douglas Bldg., Los Angeles, Cal. | June 16, 1885 |
| Hudson, C. H., . . . . . . . . .<br>Consulting Engineer, 1021 Circle Park, Knoxville, Tenn. | Nov. 14, 1876 |
| Hughes, Wm. McKenzie, . . . . . .<br>Consulting Bridge Engineer, 1511 Great Northern Bldg., Chicago. | Dec. 21, 1892 |
| Hull, Julian S., . . . . . . . . .<br>Engineer of Construction, McArthur Bros. Company, 810 Fisher Bldg., Chicago. | June 5, 1896 |
| HUNT, ROBERT W., (*Past-President.*) . . . .<br>Robert W. Hunt & Co., 1121 The Rookery, Chicago. | June 3, 1891 |
| Hurd, Chas. Henry, . . . . . . . . .<br>Mechanical Engineer in Motive Power Dept., Armour & Co., Chicago. | Jan. 2, 1900 |
| Huston, Richard C., . . . . . . . .<br>Civil and Contracting Engineer, R. 1004, 112 South Clark St., Chicago. | Sept. 14, 1901 |

| NAME | ELECTED |
|---|---|
| Illsley, Wm. A.,<br>326 Reaper Block, Chicago. | June 15, 1891 |
| Jackman, H. H.,<br>First Asst. Engr., C. W. R. R. Co., Marlinton, West Va. | July 5, 1901 |
| Jackson, Dugald C.,<br>Consulting Engineer and Expert, Professor of Electrical Engineering, University of Wisconsin, Madison, Wis. | Feb. 4, 1891 |
| Jackson, John F.,<br>Contracting Engineer, Wisconsin Bridge & Iron Co., Houghton, Mich. | June 6, 1902 |
| Jacobson, Samuel Louis,<br>Asst. Engr., Southern Railway, Middlesboro, Ky. | Jan. 25, 1901 |
| Jenison, Edward Spencer,<br>C. E. and M. E., Hydraulic Engineer, 4356 Ellis Ave., Chicago. | July 6, 1897 |
| Johnson, E. E.,<br>Mgr. Engineering Dept., Chas. A. Stickney Co., St. Paul, Minn. | Dec. 5, 1894 |
| Johnson, Gustavus J.,<br>Chemist, Raymond Lead Co., 59 West Lake St., Chicago. | Associate Jan. 1, 1899<br>Active M., Mar. 21, 1900 |
| Johnson, Lorenzo M.,<br>Gen'l Mgr. Mexican International R. R. Co., Ciudad Porfirio Diaz, Coahuila, Mexico. | Mar. 7, 1876 |
| JOHNSTON, THOS. T., *(Past-President.)*<br>Civil Engineer, 906 Security Bldg., Chicago. | Jan. 4, 1887 |
| Kandeler, Theo.,<br>Bridge Engineer, 1616 Monadnock Block, Chicago. | Aug. 22, 1890 |
| Karner, William J.,<br>Illinois Central R. R. Co., No. 1 Park Row, Chicago. | Mar. 5, 1890 |
| Katte, Walter,<br>Consulting Civil Engineer, P. O. Box 136, Irvington-on-Hudson, New York. | July 12, 1869 |
| Keating, William T.,<br>C. E., with Lorimer, Gallagher & Walsh Construction Co., 639 The Rookery, Chicago. | Dec. 3, 1895 |
| Keller, Charles L.,<br>First Asst. Engineer, Scherzer Rolling Lift Bridge Co., 1616 Monadnock Block, Chicago. | Jan. 28, 1890 |
| Kellogg, Frank Preston,<br>Structural Engineer, 2440 Indiana Ave., Chicago. | Oct. 3, 1894 |
| Kemble, Chas. P.,<br>M. E., care J. Mohr & Sons, 32-42 Illinois St., Chicago. Not a member in 1894-5-6-7-8-9. | Oct. 7, 1891 |

| NAME | ELECTED |
|---|---|
| Kerr, Chas. Volney,<br>Professor Mechanical Engineering, Armour Institute of Technology, Chicago. | Jan. 11, 1897 |
| Ketchum, Richard B.,<br>Chief Draftsman, Oregon Short Line R. R., Resident Engineer's Office, Salt Lake City, Utah. | Apr. 13, 1901 |
| Kimball, Granville,<br>Springfield Boiler & Mfg. Co., 1006-7 Marquette Bldg., Chicago. | Dec. 21, 1892 |
| Kirchoffer, William Gray,<br>City Engineer, Baraboo, Wis. | Junior July 31, 1899<br>Active M. May 10, 1901 |
| Klossowski, T. J.,<br>Care McClintick-Marshall Construction Co., Pittsburgh, Pa. | Junior Jan. 1, 1899<br>Active M. Mar. 7, 1900 |
| Kramer, William,<br>Surveyor, R. 76, 125 La Salle St., Chicago. | Mar. 1, 1898 |
| Krum, Charles L.,<br>Gen'l Supt. Western Cold Storage Co., 39 N. State St., Chicago. | June 10, 1902 |
| Kuntsman, Robert,<br>Consulting and Mechanical Engineer, 84 Adams Street, Chicago. | Apr. 3, 1902 |
| Lamont, Robert P.,<br>First Vice-Pres. Simplex Ry. Appliance Co., Hammond, Ind. | Oct. 3, 1894 |
| Langenheim, Wm. G.,<br>Asst. Bridge Engr., Sanitary District of Chicago. | June 6, 1902 |
| Lary, John Henry,<br>Asst. Engineer, C., R. I. & P. Ry, Marion, Iowa. | July 5, 1893 |
| Lederle, George A.,<br>Christie, Lowe & Heyworth, Contractors, 171 La Salle St., Chicago. | Jan. 2, 1895 |
| Lee, E. H.,<br>Engineer and General Road Master, C. & W. I. R. R., R. 45, Dearborn Station, Chicago. | Nov. 7, 1889 |
| Lee, William,<br>Asst. Engr., Sewer Dept., 207 City Hall, Chicago. | Apr. 2, 1890 |
| Lewis, James A.,<br>C. E., 1739 N St., N. W., Washington, D. C. | Dec. 21, 1892 |
| Liljencrantz, G. A. M.,<br>U. S. Assistant Engineer, 1637 Indiana Ave., Chicago. | Jan. 18, 1878 |
| Linday, Geo. N.,<br>Bridge Engineer, American Bridge Co., 120 Van Buren St., Chicago. | July 1, 1899 |
| Long, James C.,<br>U. S. Assistant Engineer, Princeton, Ill. | Sept. 7, 1895 |
| Lotter, H. H.,<br>Asst. Engr. S. Ill. & Mo. Bridge Co., Thebes Bridge, Thebes, Ill. | Junior Jan. 1, 1899<br>Active M. Mar. 7, 1900 |

| NAME | ELECTED |
|---|---|
| Love, William S.,<br>Mgr. Western Office, Wheeler Condenser and Engineering Co., 1642 Monadnock Block, Chicago. | Sept. 9, 1899 |
| Lowe, Jesse,<br>Christie, Lowe & Heyworth, Civil Engineers and Contractors, 171 La Salle St., Chicago. | Jan. 2, 1895 |
| Loweth, Chas. F.,<br>Engr. and Supt. Bridges and Buildings, C., M. & St. P. Ry., 1100 Old Colony Bldg., Chicago. | Jan. 14, 1901 |
| Luck, Charles J.,<br>Sec'y, Sinclair Construction Co., 1204 Monadnock Block, Chicago. | June 4, 1902 |
| Ludlow, Chas. G.,<br>Western Manager, Crosby Steam Gauge & Valve Co., 21-23 W. Lake St., Chicago. | July 9, 1901 |
| Lydon, William A.,<br>Pres. Lydon & Drews Co., Dredging and Docking Contractors, 1322 Chamber of Commerce, Chicago. | Sept. 6, 1887 |
| Lyons, James K.,<br>Asst. Div. Engr., American Bridge Co., 51st and Butler Sts., Pittsburgh, Pa. | Mar. 6, 1889 |
| Macdonald, David,<br>Topographer, 1355 55th St., Borough Park, Brooklyn, N. Y. | Mar. 2, 1898 |
| Macdonald, Fred. A.,<br>Civil Engineer, West Liberty, Iowa. | Feb. 3, 1892 |
| Macdonald, Jas.,<br>Pres. Macdonald Engineering Co., 1456 Monadnock Block, Chicago. | Sept. 28, 1891 |
| Maddock, Henry S.,<br>Traveling Auditor, C. & N. W. Ry., 1027 Chicago Ave., Evanston, Ill. | Sept. 5, 1888 |
| Maher, Daniel W.,<br>Ass't Engr., Board of Local Improvements, 207 City Hall, Chicago. | June 5, 1889 |
| Mallette, James P.,<br>Eggleston and Mallette, Real Estate, 1009 New York Life Bldg., Chicago. | Mar. 3, 1891 |
| Maloney, James E.,<br>Civil Engineer, 1091 Atlantic Ave., Brooklyn, N. Y. | May 3, 1893 |
| Mann, Louis M.,<br>U. S. Asst. Engineer, in charge Fox River Improvement, Oshkosh, Wis. | Dec. 3, 1889 |
| Marston, Anson,<br>Professor of Civil Engineering, Iowa State College, Ames, Iowa. | July 1, 1899 |

| NAME | ELECTED |
|---|---|
| Marx, Charles David.<br>Professor of Civil Engineering and Consulting Engineer, Stanford University P. O., Santa Clara Co., Cal. | Oct. 24, 1890 |
| Maury, Dabney H.,<br>Consulting Engineer, 129 N. Jefferson Ave., Peoria, Ill. | June 2, 1806 |
| Maxon, Robbins Y.,<br>Res. Engr. Cape Breton Ry. Co.<br>P. O. Box 46, Danville, Ill. | Junior Sept. 7, 1897<br>Active M., Oct. 3, 1900 |
| McAllen, Wm J.,<br>600 E. Division St., Chicago. | Jan. 6, 1902 |
| McCartney, Wm. M.,<br>1010 Security Bldg., Chicago. | May 24, 1807 |
| McCloy, Wm.,<br>Chief Engineer, G. R. & S. Ry., Grand Rivers Ky. | May 13, 1899 |
| McCulloch, Richard,<br>Asst. Gen'l Mgr., Chicago City Railway, 2020 State St., Chicago. | Nov. 11, 1901 |
| McDonnell, Robert Emmett,<br>Burns & McDonnell, 607 Postal Telegraph Bldg., Kansas City, Mo. | May 16, 1901 |
| McKinnon, John B.,<br>M. E., Buda Foundry & Mfg. Co., 917 Monadnock Block, Chicago. | June 15, 1891 |
| McVean, John J.,<br>Consulting Engineer, 71 State St., Grand Rapids, Mich. | Oct. 3, 1882 |
| Mead, Daniel W.,<br>Consulting Engineer, 605 First National Bank Bldg., Chicago. | Mar. 1, 1887 |
| Meadows, Harvey H.,<br>Mgr. South Eastern Office,<br>The Babcock & Wilcox Co., of New York.<br>817 Equitable Bldg., Atlanta, Ga. | Junior Mar. 2, 1897<br>Active M. Feb. 1, 1898 |
| Means, Walter K.,<br>U. S. Asst. Engr., Government Bldg., Milwaukee, Wis. | Mar. 11, 1901 |
| Melcher, Chas. W.,<br>Western Manager, The Ingersoll-Sergeant Drill Co., Old Colony Bldg., Chicago. | Nov. 5, 1895 |
| Merriam, Lauren B.,<br>Res. Engr., C. & W. Ry., 502 Bank Bldg., Trinidad, Colo. | Mar. 5, 1895 |
| Merrick, Albert W.,<br>Div. Engr., C. & N. W. Ry., Eagle Grove, Iowa. | May 6, 1901 |
| Metcalf, John S.,<br>Pres. John S. Metcalf Co., 804 The Temple, Chicago. | Sept. 28, 1891 |
| Miller, E. D.,<br>C. E., 1482 Washington Blvd., Chicago. | Dec. 21, 1892 |

| NAME | ELECTED |
|---|---|
| Miller, Hiram Allen, . . . . . . . . . . .<br>Engineer Reservoir Department, Metropolitan Water Works, 124 Walnut St., Clinton, Mass. | June 7, 1893 |
| Millerd, Harry L., . . . . . . . . . . .<br>1153 Lawndale Ave., Chicago. | Oct. 3, 1900 |
| Milligan, Robert E., . . . . . . . . . . .<br>Chemical Engineer, N. Y.-Cont'l.-Jewell Filtration Co., 40 W. Quincy St., Chicago. | Jan. 3, 1902 |
| Miltimore, Guy, . . . . . . . . . . .<br>Asst. Engr., Intercepting Sewers, 220 City Hall, Chicago. | Jan. 28, 1899 |
| MODJESKI, RALPH, (*First Vice-President.*) .<br>Consulting Civil Engineer, 1742 Monadnock Block, Chicago. | Dec. 7, 1892 |
| Mohr, Louis, . . . . . . . . . . .<br>Consulting Engineer and Sec'y of John Mohr & Sons, 32 Illinois St., Chicago. | Aug. 3, 1886 |
| Monroe, Wm. S., . . . . . . . . . . .<br>M. E., Sargent & Lundy, 46 Van Buren St., Chicago. | Aug. 19, 1901 |
| Moore, Carlton F., . . . . . . . . . . .<br>With Oliver Iron Mining Co., Duluth, Minn. | July 18, 1902 |
| Morava, Wensel, . . . . . . . . . .<br>Pres. Morava Construction Co., 1243 Marquette Bldg., Chicago. | Dec. 5, 1900 |
| Morgan, Dwight Cadogan, . . . . . . .<br>Asst. Engr., C., St. P., M. & O. Ry., Sioux City, Iowa. | Dec. 30, 1890 |
| Morgan, Richard Price, . . . . . . . . .<br>Richard P. Morgan & Son, Civil Engineers and Railway Experts, Dwight, Ill. | Jan 4, 1887 |
| Morison, George S., . . . . . . . . . .<br>Civil Engineer, 49 Wall St., New York City. | Oct. 9, 1879 |
| Morse, Charles James, . . . . . . . .<br>1825 Asbury Ave., Evanston, Ill. | Sept. 26, 1890 |
| Moth, Robert H., . . . . . . . . . . .<br>City Engineer and Supt. W. W., City Hall, Kenosha, Wis. | June 5, 1900 |
| Mott, Arthur D., . . . . . . . . . . .<br>Ritter & Mott, Civil Engineers, 1433 Marquette Bldg., Chicago. | Apr. 19, 1892 |
| Murphy, Edgar, . . . . . . . . . . .<br>Div. Engr., C., B. & Q. Ry., Galesburg, Ill. | Sept. 9, 1901 |
| Murphy, Edward J., . . . . . . . . . . .<br>With John Lundie, Consulting Engineer, 52 Broadway, New York City. | June 2, 1896 |
| Murray, Edward, . . . . . . . . . . .<br>Asst. Engr. C., M. & St. P. Ry., 1100 Old Colony Bldg., Chicago. | June 14, 1901 |
| Neureuther, Andrew H., . . . . . . . .<br>M. E., Peru, Ill. | June 23, 1902 |

| NAME | ELECTED |
|---|---|
| Nichol, John.<br>C. E., 21 Quincy St., Chicago. | Mar. 7, 1876 |
| Nicholl, T. J.,<br>Vice-Pres. Rochester Railway Co., 267 State St., Rochester, N. Y. | Sept. 10, 1872 |
| Nichols, George Perry,<br>Geo. P. Nichols & Bro., 926 Monadnock Block, Chicago. | Nov. 7, 1894 |
| Nichols, Lewis A.,<br>Pres. Nichols Engineering & Contracting Co., 508 Temple Court Bldg., Chicago. | Oct. 28, 1899 |
| Nichols, Samuel French,<br>Geo. P. Nichols & Bro., 926 Monadnock Block, Chicago. | Feb. 25, 1896 |
| NOBLE, ALFRED, (*Past-President.*)<br>20 West 34th St., New York City. | Dec. 20, 1893 |
| Olmsted, L. S.,<br>General Engineering, Drainage and Bridging, Jacksonville, Ills. | Feb. 2, 1875 |
| Orr, Robert E.,<br>Engineer E., J. & E. Ry. Co., 105 Second Ave., Joliet, Ill. | Apr. 6, 1892 |
| Ostrom, John N.,<br>C. E., Bridge Engineer, 1525 Frick Bldg., Pittsburgh, Pa. | May 4, 1886 |
| Oven, Frederick W., von,<br>Consulting and Contracting Engineer, Love Bros. Iron Works, Aurora, Ills. | Sept. 9, 1901 |
| Page, John W.,<br>Page & Shnable, Engineers and Contractors, 907 Security Bldg., Chicago. | Mar. 1, 1898 |
| Paige, Alonzo W.,<br>34 West 17th Street, New York City. | Dec. 13, 1869 |
| Paradis, F. E.,<br>Chief Engineer C. T. T. R. R. Co., 353 Grand Central Passenger Sta., Chicago. | Jan. 11, 1897 |
| Parker, W. A.,<br>Div. Engr. U. P. R. R. Co., 12th and Liberty Sts., Kansas City, Mo. | Feb. 3, 1892 |
| Parkhurst, Henry Williams,<br>Engineer Bridges and Buildings, Illinois Central System, No. 1 Park Row, Chicago. | Jan. 7, 1879 |
| Parvin, Theodore Warren,<br>Mining Engineer, Montezuma Lead Co., Santa Barbara, State of Chihuahua, Mex. | May 6, 1801 |
| Pearce, Wm. H.,<br>Sec'y and Treas. Pearce Construction Co., R. 412, 269 Dearborn St., Chicago. | Apr. 5, 1901 |
| Pence, William David,<br>Professor of Civil Engineering, Purdue University, Lafayette, Ind. | Jan. 4, 1893 |

| NAME | ELECTED |
|---|---|
| Perrigo, B. W.,<br>Assistant City Engineer, City Hall, Milwaukee, Wis. | Apr. 5, 1902 |
| Pickels, William D.,<br>Sec'y American Engineering Specialty Co., 1506-10 Monadnock Block, Chicago. | Apr. 30, 1895 |
| Poetsch, Charles J.,<br>City Engineer and President Board of Public Works, City Hall, Milwaukee, Wis. | Apr. 10, 1902 |
| Porter, Henry H.,<br>Room 503, Ellsworth Bldg., Chicago. | June 1, 1886 |
| Potter, William Gray,<br>Asst. Engr. for J. L. Ludlow, Columbus, Miss. | Feb. 4, 1891 |
| Pound, Nicholas D.,<br>Pound Construction Co., 27 Metropolitan Block, Chicago. | Apr. 2, 1895 |
| POWELL, AMBROSE VINCENT, *(Past-President.)*<br>Consulting Civil Engineer, 1008 Chamber of Commerce, Chicago. | Apr. 5, 1881 |
| Pratt, William Henry,<br>General Superintendent North Works, Illinois Steel Co., 50 Wabansia Ave., Chicago. | June 5, 1899 |
| Prell, John Stillman,<br>Civil and Mechanical Engineer, 597 Ellis St., San Francisco, Cal. | Feb. 1, 1898 |
| Price, William Gunn,<br>Engineer for Peckham Mfg. Co., 97 Clifton Ave., Kingston, N. Y. | Jan. 11, 1897 |
| Prior, Joseph H.,<br>Bridge Draftsman for Ralph Modjeski, 1742 Monadnock Block, Chicago. | Oct. 20, 1898 |
| Purdy, Corydon T.,<br>Chief Engineer, Geo. A. Fuller Co., 137 Broadway, New York. | Sept. 4, 1889 |
| Quade, John C.,<br>Civil Engineer for Western Tube Co., Kewanee, Ill. | Junior Jan. 11, 1897<br>Active Mar. 10, 1902 |
| Randolph, Henry Isham,<br>Asst. Engr. Southern Railway, Morgantown, N. C. | Mar. 7, 1900 |
| RANDOLPH, ISHAM, *(Past-President.)*<br>Chief Engineer, Sanitary District of Chicago, R. 1010, Security Bldg., Chicago. | Apr. 5, 1881 |
| Ransome, Ernest Leslie,<br>Consulting Concrete Engineer, 11 Broadway, New York City. | Nov. 7, 1894 |
| Redman, Chas. Herbert,<br>Office Resident Engineer, G. R. & I. Ry., Grand Rapids, Mich. | July 3, 1899 |

| NAME | ELECTED |
|---|---|
| Reeves, William T.,<br>Mgr. Bridge Dept. Robert W. Hunt & Co., 1121 The Rookery, Chicago | July 11, 1902 |
| Reichmann, Albert,<br>Asst. Engr., American Bridge Co., 1318 Monadnock Block, Chicago. | Dec. 10, 1897 |
| Reynolds, J. J.,<br>421 45th St., Chicago. | June 2, 1890 |
| Rice, George S.,<br>Consulting Engineer, Whitebreast Fuel Co., of Illinois, 734 The Rookery, Chicago. | June 6, 1901 |
| Rice, Luther V.,<br>Receiver Ferris Wheel Co., 1288 N. Clark St., Chicago. | Dec. 10, 1901 |
| Rich, Ben C.,<br>Asst. Engr. Lake Michigan Land Co., Chicago. | July 11, 1902 |
| Richter, Paul K.,<br>1203 Manhattan Bldg., Chicago. | Apr. 3, 1888 |
| Ricker, N. Clifford,<br>Dean of the College of Engineering, University of Illinois, Urbana, Ill. | June 6, 1902 |
| Ripley, Joseph,<br>General Superintendent-St. Mary's Falls Canal, Sault Ste. Marie, Mich. | Aug. 6, 1896 |
| Ritter, Louis E.,<br>Ritter & Mott, Civil Engineers, 1433 Marquette Bldg., Chicago. | July 3, 1901 |
| Roberts, Charles N.,<br>C. E., 709 Reaper Block, Chicago. | Apr. 6, 1892 |
| Roberts, Warren R.,<br>Consulting Engineer, Structural Iron Work, 1440 Marquette Bldg., Chicago. | Dec. 30, 1890 |
| Robinson, Eugene M.,<br>Asst. Engr. C. & N. W. Ry., 22 Fifth Ave., Chicago. | Nov. 7, 1894 |
| Robinson, James Selden<br>Division Engineer C. & N. W. Ry., No. 1 W. Kinzie St., Chicago. | Feb. 3, 1892 |
| Roemheld, J. E.,<br>Roemheld & Gallery, Contractors, 719 Chamber of Commerce, Chicago. Not a member in 1893-4-5. | June 5, 1889 |
| Rogers, Chas. W.,<br>M. E., 281-289 S. Clinton St., Chicago. | May 9, 1902 |
| Rogers, Walter A.,<br>Vice-Pres. Bates & Rogers Construction Co., 1203 Manhattan Bldg., Chicago. | Oct. 20, 1898 |
| Rohrer, Jacob Bomberger,<br>Engr. Honolulu Rapid Transit & Land Co., Thurston and Green Sts., Honolulu, H. I. | May 2, 1894 |

| NAME | ELECTED |
|---|---|
| Rosencrans, Edwin J.,<br>Jackson, Rosencrans & Canfield, Architects, 160 Fifth Ave., New York City. | Oct. 20, 1898 |
| Rounseville, D.,<br>Div. Engr., C. & N. W. Ry., Kaukauna, Wis. | May 20, 1901 |
| Rowe, Samuel McMath,<br>Consulting Engineer, Room 802, 226-8 La Salle St., Chicago. | Feb. 3, 1892 |
| Royse, Daniel,<br>Editor, Windsor & Kenfield Publishing Co., 45-47 Plymouth Place, Chicago. | Mar. 24, 1897 |
| Rust, Henry A.,<br>Business Mgr. The University of Chicago, 135 Adams Street, Chicago. | Nov. 6, 1877 |
| Rutledge, Arthur E.,<br>A. E. Rutledge & Co., Rockford, Ill. | Mar. 7, 1894 |
| Ryland, Samuel V.,<br>Operating Mines, Union Safe Deposit Vault, Stockton, Cal. | June 2, 1890 |
| Sager, Nelson A.,<br>Engineer of Intercepting Sewers of Chicago, Room 220, City Hall, Chicago. | Jan. 28, 1899 |
| Salmon, W. W.,<br>President Taylor Signal Co., Buffalo, N. Y. | Feb. 3, 1892 |
| Saltar, John, Jr.,<br>President and Engineer, The Otto Gas Engine Works, 33rd and Walnut Sts., Philadelphia, Pa. | Oct. 7, 1884 |
| Sample, John C.,<br>With Illinois Steel Co., 2531 Magnolia Ave., Edgewater, Ill. | June 23, 1902 |
| Sanborn, Wallis R.,<br>Engr. and Draftsman, Indiana, Illinois & Iowa R. R., Kankakee, Ill. | Mar. 21, 1900 |
| Sanne, Oscar,<br>Asst. Engr., care Manhattan Railway Co., 32 Park Place, New York. | Mar. 1, 1898 |
| Sargent, Fitz William,<br>Chief Engineer, The American Brake Shoe & Foundry Co., Mahwah, Bergen Co., N. J. | June 5, 1899 |
| Sargent, Frederick,<br>Sargent & Lundy, Mechanical and Electrical Engineers, 46 E. Van Buren St., Chicago. | Mar. 1, 1898 |
| Sattley, R. C.,<br>Supt. B. & B., C. & N. W. Ry. Co., Wells St. Depot, Chicago. | Aug. 6, 1901 |
| Schaefer, J. V.,<br>With Link Belt Machinery Co., 39th St. and Stewart Ave., Chicago. | Dec. 4, 1901 |

| NAME | ELECTED |
|---|---|
| Schaub, J. W.,<br>Consulting Engineer, 1650 Monadnock Block, Chicago. | Feb. 13, 1902 |
| Schenck, A. A.,<br>Division Engr., C. & N. W. Ry., Boone, Iowa. | July 1, 1899 |
| Schrader, A. C.,<br>Chief Engineer West Chicago Park Com., Union Park, Chicago. | Mar. 4, 1891 |
| Schroeter, C.,<br>Chemist, Civil and Mining Engineer, 222 Evergreen Ave., Chicago. | May 10, 1901 |
| Seddon, James A.,<br>Civil Engineer, 906 Security Bldg., Chicago. | Mar. 7, 1900 |
| Sewall, Joseph S.,<br>St. Anthony Park, St. Paul, Minn. | May 7, 1878 |
| Seymour, Robert B.,<br>Chief Engineer, Chesapeake & Western Ry. Co., 141 Broadway, New York City. | Dec. 30, 1890 |
| Seymour, Rudgeley D.,<br>Trenton Iron Co., 1711 Tremont St., Denver, Colo. | Jan. 11, 1897 |
| Shankland, Edward Clapp,<br>E. C. & R. M. Shankland, 1106 The Rookery, Chicago. | Associate July 5, 1881<br>Active M. Oct. 4, 1887 |
| Shankland, Ralph M.,<br>E. C. & R. M. Shankland, 1106 The Rookery. Not a member in 1894-5-6-7-8. | May 7, 1890 |
| Shaw, Walter A.,<br>Civil Engineer, 220 City Hall, Chicago. | Oct. 3, 1900 |
| Sheldon, Adelbert,<br>Engineering Dept. Fort Pitt Bridge Works, Canonsburg, Pa. | Jan. 3, 1899 |
| Sherman, Leroy K.,<br>Asst. Engr. West Chicago Parks, Union Park, Chicago. | Dec. 3, 1895 |
| Shields, W. S.,<br>Civil and Sanitary Engineer, 1715 Marquette Bldg., Chicago. | July 31, 1899 |
| Shnable, E. R.,<br>Page & Shnable, 907 Security Bldg., Chicago. | Feb. 4, 1891 |
| Simonds, O. C.,<br>Landscape Gardener, Buena Ave., Chicago. | Aug. 3, 1886 |
| Slifer, Hiram J.,<br>Supt. C. & N. W. Ry., Boone, Iowa. | Sept. 7, 1897 |
| Sloan, David,<br>Chief Engr. of Construction, Illinois Central R. R., No. 1 Park Row, Chicago. | Mar. 1, 1898 |
| Sloan, William Griffith,<br>Engineer, with James Stewart & Co., 1208 Westinghouse Bldg., Pittsburgh, Pa. | Junior July 1, 1890<br>Active M. June 23, 1902 |

| NAME | ELECTED |
|---|---|
| Smith, Ernest F.,<br>Assistant to Chief Operating Engineer, Chicago Edison Co., 139 Adams St., Chicago. | Jan. 3, 1902 |
| Smith, Gilman W.,<br>Erecting Manager, American Bridge Co., 1247 Monadnock Block, Chicago. | Sept. 9, 1901 |
| Smith, Owen T.,<br>Engr. and Supt. Freeport Water Co., Freeport, Ill. | June 6, 1902 |
| Smith, William Penn,<br>Civil Engineer, 1017 Monadnock Block, Chicago. | Mar. 11, 1899 |
| SMITH, GEN. WILLIAM SOOY. *(Past-President.)*<br>Civil Engineer, Wm. Sooy Smith & Co., Engineering Works Generally, 733-4 Stock Exchange Bldg., Chicago. | Oct. 8, 1874 |
| Smith, Willard A.,<br>Pres. The Railway & Engineering Review, 1305 Manhattan Bldg., Chicago. | Feb. 4, 1891 |
| Snow, Theodore Wilbur,<br>Manager Otto Gas Engine Works, 360 Dearborn St., Chicago. | Associate Dec. 5, 1894<br>Active M. Mar. 17, 1896 |
| Snyder, Christopher Henry,<br>Representative of Milliken Bros., Brewer Block, Honolulu, H. I. | Oct. 20, 1894 |
| Sooysmith, Charles,<br>Consulting Engineer, 71 Broadway, New York City. | Mar. 6, 1877 |
| Sorge, A., Jr.,<br>M. E., Feed Water Purification and Steam Purification, 1019-21 Monadnock Block, Chicago. | May 2, 1900 |
| Spaak, Charles Eric,<br>Chief Engineer, Indiana Natural Gas & Oil Co., 14 E. Monroe St., Chicago. | July 11, 1888 |
| Spelman, James,<br>With John S. Metcalf Co., 804 The Temple, Chicago. | June 5, 1902 |
| Spengler, John H.,<br>Assistant City Engineer, 325 City Hall, Chicago. | June 2, 1890 |
| Sperry, Henry M.,<br>Signal Engineer and Agent, The Union Switch & Signal Co., 143 Liberty St., New York City. | Feb. 3, 1892 |
| Spicer, V. K.,<br>Signal Engineer and Agent, The Union Switch & Signal Co., 1535 Monadnock Block, Chicago. | Feb. 3, 1892 |
| Springer, Geo. B.,<br>Civil Engineer, Chicago Edison Co., 139 Adams St., Chicago. | Dec. 5, 1890 |
| Stannard, H. E.,<br>Division Engineer, C. & N. W. Ry., No. 1 W. Kinzie St., Chicago. | May 6, 1901 |

| NAME | ELECTED |
|---|---|
| Stearns, Robert B.,<br>Supt. Northwestern Elevated R. R., 1527 Kenmore Ave., Chicago. | Apr. 20, 1901 |
| Stebbings, Walter L.,<br>Civil and Consulting Engineer, 1110 Monadnock Block, Chicago. | Jan. 6, 1890 |
| Steinbeck, E. J.,<br>Chief Clerk to Chief Engineer, I. C. R. R. No. 1 Park Row, Chicago. | Sept. 17, 1901 |
| Stephens, James S.,<br>Pres. Stephens Engineering Co., 774 The Rookery, Chicago. | July 7, 1896 |
| Stevens, Hubert A.,<br>City Engineer, Joliet, Ill. | Mar. 1, 1887 |
| Stewart, Clinton B.,<br>Civil Engineer, Anchor, Ill. | Oct. 24, 1890 |
| Stickney, Samuel Crosby,<br>General Manager, Chicago Great Western Ry., St. Paul, Minn. | Oct. 24, 1890 |
| Stowell, Chas. C.,<br>Civil Engineer, 328 N. 4th St., Rockford, Ill. | Mar. 1, 1893 |
| Strauss, Joseph B.,<br>Chief Engineer, Hall Bascule Bridge Co., 97 Washington St., Chicago. | Dec. 8, 1899 |
| Strobel, Charles L.,<br>Consulting and Contracting Engineer, Bridges and Structural Iron Work, 1744 Monadnock Block, Chicago. | Mar. 2, 1886 |
| Stucker, Noah E.,<br>With McShane Elmore & Co., 303 So. 13th St., Omaha, Neb. | Oct. 5, 1892 |
| Suckow, V. C.,<br>1742 Monadnock Block, Chicago. | Aug. 24, 1901 |
| Summers, Leland L.,<br>Consulting Engineer, 441 The Rookery, Chicago. | Dec. 3, 1895 |
| Sutter, John H.,<br>With Wm. Sooy Smith & Co., 734 Stock Exchange Bldg., Chicago. | May 7, 1901 |
| Sweatt, Barton J.,<br>Div. Engr. and Supt. Bridges and Buildings, C. & N. W. Ry., Mason City, Iowa. | July 9, 1901 |
| Sweeney, John M.,<br>Steel Cable Engineering Co. and Bradley Pulverizing Co., Griffin Mills, 1233 Monadnock Block, Chicago. | Dec. 10, 1901 |
| Taggart, John B.,<br>County Surveyor, Delaware, Ohio. | June 20, 1901 |
| Talbot, Arthur N.,<br>Professor of Municipal and Sanitary Engineering, University of Illinois, Urbana, Ill. | July 5, 1887 |

| NAME | ELECTED |
|---|---|
| Tarbet, Wm. L.,<br>Tax Commissioner, I. C. R. R. Co., No. 1 Park Row, Chicago. | Jan. 28, 1899 |
| Taylor, James J.,<br>Engineering Staff, care N. S. Steel & Coal Co., North Sydney, Nova Scotia, Can. | Nov. 14, 1901 |
| Taylor, William D.,<br>Professor of Railway Engineering, University of Wisconsin, Madison, Wis. | Apr. 4, 1901 |
| Tenny, M. W.,<br>With Pennsylvania, Long Island R. R. Extension Co., 20 West 34th St., New York City. | Junior Jan. 1, 1899<br>Active M. Mar. 4, 1902 |
| Thomas, Benjamin,<br>Pres. and Gen'l Mgr., C. & W. I. & Belt Railway Companies, R. 11, Dearborn Sta., Chicago. | May 6, 1891 |
| Thomas, George Edward,<br>Consulting Civil Engineer, care Hotel Maryland, Annapolis, Md. | Aug. 1, 1894 |
| Thomas, Marion Ellis,<br>With C. & N. W. Ry., 411 Sixth Ave., Clinton, Ia. | Junior Feb. 25, 1896<br>Active M. Mar. 7, 1900 |
| Thompson, Edgar B.,<br>M. E., C. & N. W. Ry., Chicago. | Mar. 10, 1902 |
| Thompson, Hugh Perronet,<br>445 W. 46th St., Chicago. | Nov. 9, 1889 |
| Torrance, Wm. M.,<br>Asst. Engr., with C. W. Hunt Co., West New Brighton, New York. | Oct. 9, 1901 |
| Torrey, Augustus,<br>Chief Engineer, M. C. R. R., Detroit, Mich. | Mar. 17, 1896 |
| Towler, Maximilian J. L.,<br>Manager American Bridge Co., Detroit Plant, Detroit, Mich. | July 10, 1889 |
| Townsend, C. McD.,<br>Major Corps of Engineers, U. S. Army, Rock Island, Ill. | Apr. 6, 1901 |
| Tratman, E. E. R.,<br>1636 Monadnock Block, Chicago. | July 1, 1899 |
| Trueman, Harmon,<br>Chief Engineer, Morden Frog & Crossing Works, 818 The Rookery, Chicago. | Jan. 19, 1897 |
| Trumbull, Morris K.,<br>Chief Draftsman Joint Track Elevation A. T. & S. F. Ry., I. C. R. R., and C. & A. Ry., 2476 Archer Ave., Chicago. | Junior Jan. 1, 1890<br>Active M. July 11, 1901 |
| Tullock, Alonzo J.,<br>Proprietor Missouri Valley Bridge & Iron Works, Leavenworth, Kansas. | Nov. 6, 1877 |

| NAME | ELECTED |
|---|---|
| Turneaure, Fred. E.<br>Professor of Bridge and Sanitary Engineering, University of Wisconsin, Madison, Wis. | Jan. 11, 1897 |
| Tutton, Chas. H.,<br>Asst. Engineer, Dept. Public Works, 13 City Hall, Buffalo, N. Y. | Dec. 4, 1877 |
| Vanderlip, Henry E.,<br>Consulting Engineer, R. 304, No. 134 Monroe St., Chicago. | May 4, 1897 |
| Vanderlip, O. H.,<br>Railroad and Municipal Surveys, R. 98, No. 163 Randolph St., Chicago. | Mar. 14, 1901 |
| Van Wakeman, John,<br>7105 Ingleside Ave., Chicago. | Apr. 5, 1901 |
| Vent, Frederick G.,<br>C., M. & St. P. Ry., 1100 Old Colony Bldg., Chicago. | Junior June 5, 1899<br>Active M. May 4, 1901 |
| Vial, Frederick K.,<br>Assistant Engineer, C. & W. I. R. R. R. 67, Dearborn Sta., Chicago. | Jan. 3, 1899 |
| Vogelsberger, Gustav,<br>With Thompson Starrett Co., 51 Wall Street, New York City | July 7 1897 |
| Vorce, L. D.,<br>Manager, American Linseed Co., South Chicago, Ill. | Mar. 19, 1902 |
| Wagner, Richard G.,<br>Pres. Wisconsin Sugar Co., 37 Builders' Exchange, Milwaukee, Wis. | Dec. 1 1896 |
| WALLACE, JOHN FINDLEY, (*Past-President.*)<br>Asst. Gen'l Mgr. I. C. R. R., Room 603, No. 1 Park Row, Chicago. | June 5, 1889 |
| Wallace, William A.,<br>Asst. Engr., C., I. & L. Ry. Co., 198 Custom House Place, Chicago. | Apr. 19, 1898 |
| WARDER, J. H., (*Secretary and Librarian.*)<br>M. E., 1737 Monadnock Block, Chicago. | Oct. 20, 1898 |
| Washburn, Frank S.,<br>Contracting Engineer, Cole Building, Nashville, Tenn. | Jan. 8, 1884 |
| Webster, Hosea,<br>100 Elm St., Montclair, N. J. | Nov. 1, 1889 |
| Wentz, Robert F.<br>Consulting Engineer, Nazareth, Pa. | Nov. 13, 1901 |
| Westcott, Oliver J.,<br>Sec'y and Treas. Stephens & Westcott, 774 The Rookery, Chicago. | Dec. 1, 1892 |
| Weston, Charles Valentine,<br>Weston Bros., Consulting and Contracting Engineers, 711 Merchants' Loan & Trust Bldg., Chicago. | Sept. 26, 1890 |

| NAME | ELECTED |
|---|---|
| Weston, George,<br>Weston Brothers, 711 Merchants' Loan & Trust Bldg., Chicago. | Apr. 6, 1892 |
| Weston, John W.,<br>Blue Island, Ill. | Jan. 2, 1877 |
| Whitley, Noah,<br>C. E., Court House, Joliet, Ill. Not a member in 1894-5-6-7. | Nov. 5, 1890 |
| Whitridge, John Clifford,<br>Buckeye Malleable Iron & Coupler Co., Columbus, Ohio. | Junior Mar. 2, 1897<br>Active M. Oct. 1, 1898 |
| Whittemore, D. J.,<br>Chief Engineer C., M. & St. P. Ry., 1100 Old Colony Bldg., Chicago. | Apr. 8, 1872 |
| Wilkins, Geo. S.,<br>Professor of Engineering, University of Alabama, University P. O., Ala. | July 3, 1899 |
| WILLIAMS, BENEZETTE, *(Past-President.)*<br>Consulting Engineer, 801 Association Bldg., Chicago. | Oct. 14, 1872 |
| Williams, Herbert Evan,<br>1522 Monadnock Block, Chicago. | Jan. 11, 1897 |
| Williams, William Erastus,<br>Sixth Floor, No. 217 So. Clinton St., Chicago. | Dec. 4, 1889 |
| Williamson, John,<br>Consulting Engineer People's Gas Light & Coke Co., 157 Michigan Ave., Chicago. | Sept. 7, 1897 |
| Willis, Paul,<br>Secretary and Engineer Kenwood Bridge Co., 417 First National Bank Bldg., Chicago. | Dec. 30, 1890 |
| Wilson, W. J.,<br>Warkworth, Auckland, New Zealand. | Feb. 15, 1902 |
| Wilmann, Edward,<br>Care D. H. Burnham & Co., 1919 Frick Bldg., Pittsburg, Pa. | July 11, 1894 |
| Windett, Victor,<br>Mgr. Nash & Dowdle, 316 Hennen Bldg., New Orleans, La. | Jan. 4, 1893 |
| Winston, William Overton,<br>Vice-Pres. Winston Bros. Co., Contractors, 801 Globe Bldg., Minneapolis, Minn. | Sept. 2, 1884 |
| Wisner, George Monroe,<br>Assistant Chief Engineer, Sanitary District, 1010 Security Bldg., Chicago. | May 17, 1896 |
| Witherspoon, John McCalla,<br>Supt. Geo. M. Moulton & Co., 1811 Fisher Bldg., Chicago. | Dec. 5, 1894 |
| Witt, Carl C.,<br>Asst. Engr. Bridge Dept., C. & N. W. Ry., R. 3, Marine Bldg., Chicago. | Jan. 12, 1901 |

| NAME | ELECTED |
|---|---|
| Wolf, Albert H.,<br>Consulting and Contracting Engineer, R. 720-1-2, No. 218 La Salle St., Chicago. | Dec. 30, 1890 |
| Wolhaupter, Benjamin,<br>Mgr. Federal Supply Co., 554 The Rookery, Chicago. | Dec. 30, 1890 |
| Worden, Beverley L.,<br>Bridge Engineer, Wisconsin Bridge & Iron Co., Pabst Bldg., Milwaukee, Wis. | Jan. 11, 1897 |
| Worden, Euclid P.,<br>M. E., Fred M. Prescott Steam Pump Co., Milwaukee, Wis. | Apr. 8, 1902 |
| WRIGHT, AUGUSTINE W., *(Past-President.)*<br>Consulting Engineer, Pomona, Cal. | May 6, 1879 |
| Wright, Joseph,<br>P. O. Box 351, Sheffield, Ill. | May 9, 1902 |
| Yale, L. P.,<br>Chief Engr., M. K. & O. R. R., Coffeyville, Kas. | June 21, 1901 |
| Ziesing, August,<br>Western Manager, American Bridge Co., 1315 Monadnock Block, Chicago. | June 5, 1889 |
| Zurcher, Max A.,<br>Bridge Engineer, Chief Engineer's Office, Canadian Pacific Ry., Montreal, Canada. | Oct. 18, 1881 |

**Active Members, 505.**

## ASSOCIATES.

*(Assoc. M. W. S. E.)*

| NAME | ELECTED |
|---|---|
| Alderson, Victor C.,<br>Dean of Armour Institute of Technology, 33rd St. and Armour Ave., Chicago. | Oct. 28, 1899 |
| Allison, John T.,<br>General Western Agent, Forcite Powder Co., 1004 Chamber of Commerce Bldg., Chicago. | Jan. 19, 1897 |
| Boldenweck, William,<br>3199 Malden St., Sheridan Park, Chicago. | Nov. 7, 1894 |
| Bryant, George H.,<br>Western Representative Thos. Prosser & Son, 1405 Old Colony Bldg., Chicago. | Apr. 2, 1895 |
| Byrne, Thomas,<br>Gahan & Byrne, General Contractors, Chicago. | Nov. 7, 1894 |
| Corbett, John T.,<br>With Jos. T. Ryerson & Sons, 18 Milwaukee Ave., Chicago. | Oct. 3, 1900 |

| NAME | ELECTED |
|---|---|
| Dickinson, John W.,<br>Portland Cement, 741 Marquette Bldg., Chicago. | Jan. 4, 1898 |
| Dietzgen, Eugene,<br>President of Eugene Dietzgen Co., 181 Monroe St., Chicago. | Sept. 7, 1886 |
| Dunham, Chas.,<br>Signal Engr., I. C. R. R., Central Station, R. 902, Park Row, Chicago. | Apr. 12, 1902 |
| Ellis, Jerome A.,<br>Ellis & Ripley, Railway Supplies, 707 Great Northern Bldg., Chicago. | Mar. 24, 1897 |
| Gardner, James W.,<br>553 The Rookery, Chicago. | Jan. 7, 1896 |
| Griffiths, John,<br>John Griffiths & Son, 1009-11 Merchants' Loan & Trust Bldg., Chicago. | Nov. 7, 1894 |
| Hall, John L.,<br>With Purdy & Henderson, 1553 Monadnock Blk., Chicago. | June 4, 1902 |
| Hubbard, Lucius Lee,<br>Gen'l Mgr., Champion Copper Co., Painesdale, Houghton Co., Mich. | July 22, 1901 |
| Johnson, Frank J.,<br>American Hoist & Derrick Co., 60 South Canal St., Chicago. | Jan. 11, 1897 |
| Leake, Thos. S.,<br>1682 88th St., Chicago. | June 11, 1902 |
| Link, Rudolph,<br>Mgr. Keuffel & Esser Co., 111 Madison St., Chicago. | Nov. 5, 1895 |
| Macomber, F. B.,<br>Sec'y-Treas. Macomber & Whyte Rope Co., 19-21 So. Canal St., Chicago. | Jan. 1, 1899 |
| McArthur, Archibald,<br>McArthur Bros. Co., 810 Fisher Bldg., Chicago. | Nov. 7, 1894 |
| McArthur, Arthur F.,<br>Treasurer McArthur Bros. Co., 810 Fisher Bldg., Chicago. | Mar. 2, 1897 |
| Moore, Olin F.,<br>928 Lincoln Trust Bldg., St. Louis, Mo. | Mar. 11, 1899 |
| Paterson, James S.,<br>Paterson, Collier & Co., 1560 Monadnock Block, Chicago. | Mar. 17, 1896 |
| Quincy, Charles F.,<br>620 Western Union Bldg., Chicago. | Apr. 2, 1895 |

| NAME | ELECTED |
|---|---|
| Reynolds, John N.,<br>Second Vice-President, Railway Age, 1660 Monadnock Block, Chicago. | July 30, 1898 |
| Ross, Arthur J.,<br>1207 Monadnock Block, Chicago. | Jan. 11, 1897 |
| Schauffler, C. E.,<br>Galena Signal Oil Co., 737 Monadnock Block, Chicago. | Jan. 2, 1895 |
| Scribner, Gilbert H., Jr.,<br>Contracting Engineer, R. 808, Merchants' Loan & Trust Co. Bldg., 135 Adams St., Chicago. | Mar. 17, 1896 |
| Seafert, William,<br>Cement and Engineering News, R. 67, No. 162 La Salle St., Chicago. | May 1, 1901 |
| Sinclair, Donald,<br>Kankakee, Ill. | Jan. 28, 1899 |
| Wilson, Hugh M.,<br>President, The Railway Age, 1660 Monadnock Block, Chicago. | Mar. 7, 1900 |
| Winston, James Overton,<br>Winston & Co., Contractors, Clinton, Mass. | Feb. 25, 1896 |

**Total, 31 Associates.**

## JUNIORS.

*(Jun. M. W. S. E.)*

| NAME | ELECTED |
|---|---|
| Aldinger, Albert Henry,<br>Draftsman, D. H. Burnham & Co., Architects, 1142 The Rookery, Chicago. | June 7, 1902 |
| Artingstall, William,<br>Civil Engineer, Sanitary District, 1005 Security Bldg., Chicago. | Mar. 29, 1901 |
| Beattys, W. H., Jr.,<br>With Sprague Electric Co., 209 Fisher Bldg., Chicago. | Jan. 6, 1902 |
| Beckman, Burchard F.,<br>Road Master, C., B. & Q. R. R., Union Depot, Burlington, Iowa. | Mar. 21, 1900 |
| Bennett, A. J. T.,<br>Estimator and Designer, Kenwood Bridge Co., R. 417, First National Bank Bldg., Chicago. | Dec. 5, 1901 |
| Bosworth, C. I.,<br>Asst. Engr. Idaho Division Oregon Short Line Ry., Pocatello, Idaho. | May 13, 1899 |
| Briggs, James,<br>Asst. Engr. O. R. J. R. R., Rochester, Pa. | Sept. 9, 1899 |
| Brownell, J. Dempster,<br>Mgr. Badger Coal Co., Janesville, Wis. | July 1, 1899 |

| NAME | ELECTED |
|---|---|
| Bruce, William Alman, . . . . . . .<br>Empire Bridge Co., Rochester, N. Y. | July 1, 1899 |
| Bunnel, W. C., . . . . . . . . . . . .<br>U. S. Junior Engineer, U. S. Engineer Office, Custom House, Charleston, S. C. | Aug. 6, 1900 |
| Button, Ernest D., . . . . . . . . . .<br>Care I. C. R. R. Co., Memphis, Tenn. | Sept. 9, 1899 |
| Clarke, Chas. W. E., . . . . . . . .<br>With Sargent & Lundy, 1000 Isabella Bldg., Chicago. | Sept. 9, 1901 |
| Clayton, Thomas Wiley, . . . . . . . .<br>Asst. Engr., C. & A. Ry., 919 Monadnock Block, Chicago. | July 3, 1899 |
| Conger, Alger Adams, . . . . . . . .<br>Asst. Engr., Michigan-Lake Superior Power Co., Sault Ste. Marie, Mich. | Jan. 3, 1899 |
| Corthell, Howard L., . . . . . . . . .<br>Asst. Engr. So. Ill. & Mo. Bridge Co., Thebes, Ill. | Dec. 4, 1901 |
| Cummins, Thomas R., . . . . . . . .<br>Road Master, St. Louis Division, Illinois Central R. R., Carbondale, Ill. | Mar. 21, 1900 |
| Cunningham, Edward Walter, . . . . . .<br>3432 Bouquet St., Pittsburgh, Pa. | Nov. 28, 1899 |
| Dakin, Henry, . . . . . . . . . . . .<br>County Surveyor, Kane County, Ill., Room 4, City Hall, Elgin, Ill. | May 2, 1900 |
| Drake, Charles S., . . . . . . . . . .<br>Asst. Engr., C. & N. W. Ry., Spencer, Neb. | Jan. 1, 1899 |
| Dunaway, Arthur N., . . . . . . . . . | Jan. 6, 1899 |
| Elliott, Louis, . . . . . . . . . . . .<br>Care Pratt & Atkins, 1001 Monadnock Block, Chicago. | May 16, 1902 |
| Ely, Howard M., . . . . . . . . . . .<br>Supt. Construction, Railroad Water Supply, care C. A. Stickney Co., St. Paul, Minn. | Apr. 18, 1901 |
| Evans, Edward M., . . . . . . . . . .<br>American Bridge Co., Lassig Branch, Chicago, Ill. | July 3, 1899 |
| Fitzpatrick, P. D., . . . . . . . . . .<br>Asst. Engr., I. C. R. R. Co., Louisville, Ky. | July 1, 1899 |
| Flanders, Louis H., . . . . . . . . . .<br>Mech. Engr. in Exp. Dept., Westinghouse Mach. Co., East Pittsburgh, Pa. | Mar. 7, 1900 |
| Fucik, Edward J., . . . . . . . . . .<br>Sub-Instrumentman, Chicago Sanitary District, 1010 Security Bldg., Chicago. | May 14, 1902 |
| Geppert, Richard M., . . . . . . . .<br>Mining Engineer, Silver Peak, Esmeralda Co., Nevada. | June 8, 1901 |

| NAME | ELECTED |
|---|---|
| Geraty, George C.,<br>Civil Engineer, The Chicago Testing Laboratory, Jonesville, Mich. | Mar. 1, 1898 |
| Grady, John E.,<br>Instrumentman, 1010 Security Bldg., Chicago. | Sept 3, 1897 |
| Hadsall, Harry H.,<br>Asst. Engr., I. C. R. R., 902 Central Station, Chicago. | Oct. 28, 1899 |
| Hasselfeldt, Ernest Chas.,<br>Draftsman, with Swift & Co., Chicago. | June 26, 1902 |
| Hermanns, F. E.,<br>1100 Old Colony Bldg., Chicago. | Apr. 12, 1902 |
| Hill, Merle D.,<br>Draftsman, Virginia Bridge Co., Roanoke, Va. | Mar. 21, 1900 |
| Hoppin, Wm. Pierce,<br>Asst. Engr., I. C. R. R. Co., Beechwood, Ill. | Mar. 11, 1902 |
| Hunt, Wilson P.,<br>Supt. Moline Tool Co., Moline, Ill. | Apr. 6, 1897 |
| Icke, John F.,<br>City Engineer, Madison, Wis. | Apr. 3, 1901 |
| Johnson, Charles,<br>U. S. Engineer's Office, 3232 Prytania St., New Orleans, La. | Jan. 8, 1902 |
| Johnson, Maro,<br>Asst. Engr. Illinois Central R. R., 903 Central Station, Chicago. | Mar. 13, 1902 |
| Knapp, Chas S.,<br>M. E., The American Clock Co., 1930 Wabash Ave., Chicago. | Jan. 17, 1899 |
| Logeman, Richard T.,<br>Res. Engr., C., M. & St. P. Ry. Co., Faribault, Minn. | July 31, 1899 |
| Lothholz, Harry C.,<br>Bridge Draftsman, American Bridge Co., Van Buren and Clark Sts., Chicago. | Mar. 11, 1901 |
| Lovewell, Maurice N.,<br>Res. Engr., B. & O. R. R., 52 Pugh Ave., Columbus, Ohio. | Jan. 9, 1901 |
| Marshall, Alfred H.,<br>R. 605, 1st National Bank Bldg., Chicago. | Mar. 20, 1902 |
| Mason, Leonard B.,<br>Bridge Designer, C., M. & St. P. Ry., 1100 Old Colony Bldg., Chicago. | May 9, 1902 |
| McDonald, Clinton,<br>Road Master, C. & N. W. Ry., Madison, Wis. | May 2, 1900 |
| Meier, William,<br>Illinois Telephone Construction Co., Chicago. | Mar. 11, 1902 |

| NAME | ELECTED |
|---|---|
| Montgomery, John T.,<br>Res. Mgr., The Roebling Construction Co., 171-3 Lake St., Chicago. | July 31, 1899 |
| Musham, John W.,<br>Draftsman, American Bridge Co., 120 E. Van Buren St., Chicago. | June 5, 1899 |
| North, William Harrison,<br>Draftsman, Hansell-Elcock Foundry Co., 23rd Pl. and Archer Ave., Chicago. | Mar. 21, 1900 |
| Phillips, T. C.,<br>John A. Cole & Son, 1580 Old Colony Bldg., Chicago. | July 16, 1901 |
| Priseler, Myron W.,<br>With Ingersoll-Sergeant Drill Co., 1510 Old Colony Bldg., Chicago. | May 3, 1902 |
| Randolph, Robert Isham,<br>Sanitary District of Chicago, 319 Grand Central Depot, Chicago. | Mar. 10, 1902 |
| Riddle, Lewis W.,<br>Kenwood Bridge Co., 417 First National Bank Bldg., Chicago. | Dec. 4, 1901 |
| Robertaccio, F. Leonardo,<br>Engineering Dept., Shaft No. 3, Illinois Telephone & Telegraph Co., 76 La Salle St., Chicago. | Jan. 3, 1902 |
| Rockwell, James Vincent,<br>Asst. Engr., C. & N. W. Ry., Division Engineer's Office, Baraboo, Wis. | July 1, 1899 |
| Rodgers, Edward H.,<br>Foreman Pickling Dept., American Tin Plate Co., Elwood, Ind. | Dec. 5, 1900 |
| Rosing, A. S.,<br>Instrumentman, C. & N. W. Ry., No. 1 West Kinzie St., Chicago. | May 4, 1901 |
| Ross, Harry Hurson,<br>Asst. Engr., L. S. & M. S. Ry., R. 26, General Offices L. S. & M. S. Ry., Cleveland, Ohio. | Jan. 14, 1897 |
| Safford, Harry Robinson,<br>Care I. C. R. R., Freeport, Ill. | May 23, 1898 |
| Schafer, Otto,<br>Asst. Engr., C., M. & St. P. Ry., Milwaukee Depot, Minneapolis, Minn. | Oct. 28, 1899 |
| Schneider, Edward John,<br>With American Bridge Co., St. Louis, Mo. | Jan. 9, 1901 |
| Smith, Robert C.,<br>Supt. for E. C. & R. M. Shankland, Civil Engineers, 150 Van Buren St., Chicago. | Oct. 3, 1899 |
| Stewart, Morton Bishop,<br>M. E., Missouri Edison Electric Co., 10th and Gratiot Sts., St. Louis, Mo. | Dec. 8, 1899 |

| NAME | ELECTED |
|---|---|
| Swanitz, H. W.,<br>Asst. Engr., I. C. R. R. Co., Freeport, Ill. | Nov. 11, 1901 |
| Theodorson, Wm. A.,<br>Draughtsman, American Bridge Co., Yukon Bldg., Chicago. | Mar. 10, 1902 |
| Van Pelt, Sutton,<br>U. S. Inspector, Lock 5, Warrior River, Akron, Ala. | Mar. 15, 1902 |
| Warder, W. J., Jr.,<br>Electrical Engineer, 242 S. Jefferson St., Chicago. | Dec. 6, 1901 |
| Warren, Alexander C.,<br>Proprietor, Hoeffer & Co., 813 Chamber of Commerce, Chicago. | Nov. 28, 1899 |
| Wray, D. C.,<br>Asst. Mine Engr., 734 The Rookery, Chicago. | July 11, 1901 |

**Total, 69 Juniors.**

## RECAPITULATION.

| | |
|---|---|
| Honorary Members | 1 |
| Active Members | 505 |
| Associate Members | 31 |
| Junior Members | 69 |
| Total membership, July, 1902 | 606 |

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*Note.—In the interest of all concerned, it is urged upon members to report every change of address promptly to

J. H. Warder, Sec'y.
Western Society of Engineers,
1737 Monadnock Blk., Chicago.

# PAST AND PRESENT OFFICERS

## PRESIDENTS.

| | | |
|---|---|---|
| *Roswell B. Mason | June 14, 1869, | to June 13, 1870 |
| Charles Paine | June 13, 1870, | to June 9, 1873 |
| *E. S. Chesbrough | June 9, 1873, | to June 19, 1877 |
| Wm. Sooy Smith | June 19, 1877, | to Aug. 3, 1880 |
| *E. S. Chesbrough | Aug. 3, 1880, | to Jan. 2, 1882 |
| *Willard S. Pope | Jan. 2, 1882, | to Jan. 8, 1883 |
| *De Witt C. Cregier | Jan. 9, 1883, | to Jan. 6, 1885 |
| Benezette Williams | Jan. 6, 1885, | to Jan. 5, 1886 |
| Augustine W. Wright | Jan. 5, 1886, | to Jan. 4, 1887 |
| Samuel G. Artingstall | Jan. 4, 1887, | to Jan. 3, 1888 |
| *A. Gottlieb | Jan. 3, 1888, | to Jan. 8, 1889 |
| E. L. Corthell | Jan. 8, 1889, | to Jan. 8, 1890 |
| L. E. Cooley | Jan. 8, 1890, | to Feb. 3, 1892 |
| Isham Randolph | Feb. 3, 1892, | to Jan. 4, 1893 |
| Robert W. Hunt | Jan. 4, 1893, | to Jan. 3, 1894 |
| Hiero B. Herr | Jan. 3, 1894, | to Jan 2, 1895 |
| Horace E. Horton | Jan. 2, 1895, | to Jan. 2, 1896 |
| John F. Wallace | Jan. 2, 1896, | to Jan. 5, 1897 |
| Thos. T. Johnston | Jan. 5, 1897, | to Jan. 4, 1898 |
| Alfred Noble | Jan. 4, 1898, | to Jan. 3, 1899 |
| Onward Bates | Jan. 3, 1899, | to Jan. 2, 1900 |
| Ambrose V. Powell | Jan. 2, 1900, | to Jan. 8, 1901 |
| Octave Chanute | Jan. 8, 1901, | to Jan. 7, 1902 |
| William H. Finley | Jan. 7, 1902. | |

## FIRST VICE-PRESIDENTS.

| | | |
|---|---|---|
| *Moses Lane | Aug. 3, 1880, | to Jan. 2, 1882 |
| *De Witt C. Cregier | Jan. 2, 1882, | to Jan. 9, 1883 |
| S. S. Greeley | Jan. 9, 1883, | to Jan. 15, 1884 |
| Isham Randolph | Jan. 15, 1884, | to Jan. 6, 1885 |
| Octave Chanute | Jan. 6, 1885, | to Jan. 5, 1886 |
| C. H. Hudson | Jan. 5, 1886, | to Jan. 4, 1887 |
| L. E. Cooley | Jan. 4, 1887, | to Jan. 3, 1888 |
| John W. Weston | Jan. 3, 1888, | to Jan. 8, 1889 |
| Chas. MacRitchie | Jan. 8, 1889, | to Jan. 8, 1890 |
| Robert A. Shailer | Jan. 8, 1890, | to Jan. 7, 1891 |
| John F. Wallace | Jan. 7, 1891, | to Jan. 6, 1892 |

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*Deceased.

| | |
|---|---|
| E. C. Carter | Jan. 6, 1892, to Jan. 4, 1893 |
| H. A. Rust | Jan. 4, 1893, to Jan. 3, 1894 |
| Daniel W. Mead | Jan. 3, 1894, to Jan. 2, 1895 |
| L. P. Morehouse | Jan. 2, 1895, to Jan. 2, 1896 |
| Thos. T. Johnston | Jan. 2, 1896, to Jan. 5, 1897 |
| Alfred Noble | Jan. 5, 1897, to Jan. 4, 1898 |
| James J. Reynolds | Jan. 4, 1898, to Jan. 2, 1899 |
| *Nelson O. Whitney | Jan. 3, 1899, to Jan. 3, 1900 |
| *Edward J. Blake | Jan. 2, 1900, to Jan. 8, 1901 |
| William H. Finley | Jan. 8, 1901, to Jan. 7, 1902 |
| Ralph Modjeski | Jan. 7, 1902. |

## SECOND VICE-PRESIDENTS.

| | |
|---|---|
| *De Witt C. Cregier | Aug. 3, 1880, to Jan. 2, 1882 |
| *Kirtland F. Booth | Jan. 2, 1882, to Jan. 9, 1883 |
| Isham Randolph | Jan. 9, 1883, to Jan. 15, 1884 |
| Augustine W. Wright | Jan. 15, 1884, to Jan. 6, 1885 |
| *Samuel McElroy | Jan. 6, 1885, to Jan. 5, 1886 |
| D. J. Whittemore | Jan. 5, 1886, to Jan. 4, 1887 |
| Ira O. Baker | Jan. 4, 1887, to Jan. 3, 1888 |
| Octave Chanute | Jan. 3, 1888, to Jan. 8, 1889 |
| *Samuel McElroy | Jan. 8, 1889, to Jan. 8, 1890 |
| W. R. Northway | Jan. 8, 1890, to Jan. 7, 1891 |
| W. O. Seymour | Jan. 7, 1891, to Jan. 6, 1892 |
| Ira O. Baker | Jan. 6, 1892, to Jan. 4, 1893 |
| Hiero B. Herr | Jan. 4, 1893, to Jan. 3, 1894 |
| H. C. Draper | Jan. 3, 1894, to Jan. 2, 1895 |
| Thos. T. Johnston | Jan. 2, 1895, to Jan. 2, 1896 |
| Alfred Noble | Jan. 2, 1896, to Jan. 5, 1897 |
| James J. Reynolds | Jan. 5, 1897, to Jan. 4, 1898 |
| A. V. Powell | Jan. 4, 1898, to Jan. 3, 1899 |
| T. L. Condron | Jan. 3, 1899, to Jan. 2, 1900 |
| William H. Finley | Jan. 2, 1900, to Jan. 8, 1901 |
| Bertrand E. Grant | Jan. 8, 1901, to Jan. 7, 1902 |
| L. P. Breckenridge | Jan. 7, 1902. |

## EXECUTIVE COMMITTEES.

| | |
|---|---|
| *W. H. Clark<br>*Max Hjortsberg | June 14, 1869, to June 8, 1874 |
| H. W. S. Cleveland<br>C. W. Durham | June 8, 1874, to June 15, 1875 |
| S. S. Greeley<br>W. M. R. French | June 15, 1875, to June 17, 1878 |
| S. S. Greeley<br>Benezette Williams | June 17, 1878, to Aug. 3, 1880 |

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*Deceased.

## TRUSTEES.

| | |
|---|---|
| S. S. Greeley<br>H. C. Nutt<br>*R. J. McClure | Aug. 3, 1880, to Jan. 2, 1882 |
| S. S. Greeley<br>*R. J. McClure<br>W. S. McHarg | Jan. 2, 1882, to Jan. 9, 1883 |
| *R. J. McClure<br>W. S. McHarg<br>W. Sooy Smith | Jan. 9, 1883, to Jan. 15, 1884 |
| W. S. McHarg<br>W. Sooy Smith<br>*R. J. McClure | Jan. 15, 1884, to Jan. 6, 1885 |
| W. Sooy Smith<br>*R. J. McClure<br>A. W. Wright | Jan. 6, 1885, to Jan. 5, 1886 |
| *R. J. McClure<br>S. G. Artingstall<br>*A. Gottlieb | Jan. 5, 1886, to Jan. 4, 1887 |
| S. G. Artingstall<br>*A. Gottlieb<br>H. A. Rust | Jan. 4, 1887, to Jan. 3, 1888 |
| *A. Gottlieb<br>H. A. Rust<br>O. B. Green | Jan. 3, 1888, to Jan. 8, 1889 |
| H. A. Rust<br>O. B. Green<br>Chas. FitzSimons | Jan. 8, 1889, to Jan. 8, 1890 |
| O. B. Green<br>Chas. FitzSimons<br>B. Williams | Jan. 8, 1890, to Jan. 7, 1891 |
| Chas. FitzSimons<br>B. Williams<br>O. Chanute | Jan. 7, 1891, to Jan. 6, 1892 |
| B. Williams<br>O. Chanute<br>C. L. Strobel | Jan. 6, 1892, to Jan. 4, 1893 |
| O. Chanute<br>C. L. Strobel<br>Geo. S. Morison | Jan. 4, 1893, to Jan. 3, 1894 |
| C. L. Strobel<br>Geo. S. Morison<br>Robt. W. Hunt | Jan. 3, 1894, to Jan. 2, 1895 |

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* Deceased.

| | |
|---|---|
| Geo. S. Morison<br>Robt. W. Hunt<br>G. A. M. Liljencrantz | Jan. 2, 1895, to Jan. 2, 1896 |
| Robt. W. Hunt<br>G. A. M. Liljencrantz<br>Horace E. Horton | Jan. 2, 1896, to Jan. 5, 1897 |
| G. A. M. Liljencrantz<br>Horace E. Horton<br>*Ferd. Hall | Jan. 5, 1897, to Jan. 3, 1898 |
| Horace E. Horton<br>*Ferd. Hall<br>Geo. P. Nichols | Jan. 1, 1898, to Jan. 3, 1899 |
| *Ferd. Hall<br>Geo. P. Nichols<br>August Ziesing | Jan. 3, 1899, to Jan. 2, 1900 |
| Geo. P. Nichols<br>August Ziesing<br>Bion J. Arnold | Jan. 2, 1900, to Jan. 8, 1901 |
| August Ziesing<br>Bion J. Arnold<br>Jas. J. Reynolds (to Sept. 11)<br>Chas. W. Hotchkiss (from Sept. 11) | Jan. 8, 1901, to Jan. 7, 1902 |
| Bion J. Arnold<br>Chas. W. Hotchkiss<br>John W. Alvord | Jan. 7, 1902. |

## SECRETARIES.

| | |
|---|---|
| L. P. Morehouse | June 14, 1869, to Jan. 3, 1888 |
| Lyman E. Cooley | Jan. 3, 1888, to Jan. 8, 1889 |
| John W. Weston | Jan. 8, 1889, to Jan. 3, 1894 |
| Thomas Appleton | Jan. 3, 1894, to Jan. 2, 1895 |
| Charles J. Roney | Jan. 2, 1895, to Mar. 4, 1896 |
| Henry Goldmark | Mar. 4, 1896, to Aug. 5, 1896 |
| Nelson L. Litten | Aug. 5, 1896, to Jan. 10, 1901 |
| J. H. Warder | Jan. 10, 1901. |

## TREASURERS.

| | |
|---|---|
| L. P. Morehouse | June 14, 1869, to Aug. 3, 1880 |
| Chas. FitzSimons | Aug. 3, 1880, to Jan. 4, 1887 |
| A. V. Powell | Jan. 4, 1887, to Jan. 3, 1888 |
| W. S. Bates | Jan. 3, 1888, to Jan. 8, 1889 |
| H. W. Parkhurst | Jan. 8, 1889, to Jan. 8, 1890 |
| John W. Weston | Jan. 8, 1890, to Jan. 4, 1893 |

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*Deceased.

| | |
|---|---|
| *Edwin G. Nourse | Jan. 4, 1893, to Jan. 3, 1894 |
| *David L. Barnes | Jan. 3, 1894, to Jan. 2, 1896 |
| Emil Gerber | Jan. 2, 1896, to Jan. 4, 1898 |
| C. W. Melcher | Jan. 4, 1898, to Jan. 2, 1900 |
| Ralph Modjeski | Jan. 2, 1900, to Jan. 7, 1902 |
| John C. Whitridge | Jan. 7, 1902, to Apr. 10, 1902 |
| Andrew Allen | Apr. 10, 1902. |

## LIBRARIANS.

| | |
|---|---|
| John W. Weston | Aug. 3, 1880, to Jan. 9, 1883 |
| G. A. M. Liljencrantz | Jan. 9, 1883, to Jan. 8, 1890 |
| John W. Weston | Jan. 8, 1890, to Jan. 3, 1894 |
| Thomas Appleton | Jan. 3, 1894, to Jan. 2, 1895 |
| Chas. J. Roney | Jan. 2, 1895, to Mar. 4, 1896 |
| Nelson L. Litten | Jan. 12, 1898, to Jan. 10, 1901 |
| J. H. Warder | Jan. 10, 1901. |

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*Deceased.

## DECEASED MEMBERS.*

| NAME | DATE OF DEATH |
|---|---|
| Adams, Edward L | January 31, 1902. |
| Adler, Dankmar | April 16, 1900. |
| Baker, William L | May 28, 1888. |
| Barnes, David Leonard | December 15, 1896. |
| Blake, Edward J | May 29, 1902. |
| Booth, Kirtland Farnum | March 23, 1892. |
| Bryson, Wm. | October 26, 1876. |
| Bullock, Milan C | January 12, 1899. |
| Card, Joseph P | October 22, 1894. |
| Casgrain, W. T | September 28, 1900. |
| Cheney, Orlando H | April 13, 1891. |
| Chesbrough, Ellis S | August 18, 1886. |
| Chesbrough, I. G | January 28, 1893. |
| Clarke, William Hull | 1879. |
| Colborne, B. B | 1893. |
| Cregier, DeWitt C | November 9, 1898. |
| Davis, Fred. H | June 21, 1901. |
| DeHart, Norwood | May 11, 1899. |
| Esson, John H | August 23, 1900. |
| Farquar, Col. F. U | July 3, 1883. |
| Ferris, G. W. G | November 22, 1896. |
| Gardner, H. A | July 26, 1875. |
| Gottlieb, Abraham | February 9, 1894. |
| Johnson, John Butler | June 23, 1902. |
| Hall, Ferdinand | November 22, 1899. |
| Hammett, Wm. A | September , 1895. |
| Healey, Jas. M | September 22, 1901. |
| Higginson, Charles M | May 6, 1899. |
| Hitz, Irving | September 24, 1901. |
| Hjortsberg, Maximilian | May 16, 1880. |
| Lake, George Bert | April 27, 1884. |
| Lane, Moses | January 25, 1882. |
| Lassig, Moritz | January 7, 1902. |
| Latimer, Charles | March 25, 1888. |
| Lewis, Jas. F | July 23, 1901. |
| Lincoln, Isaac | March 13, 1894. |
| Lotz, William Herman | January 31, 1894. |
| Mason, Col. Eddy D | December 19, 1874. |
| Mason, Roswell B | January 1, 1892. |

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*This list is incomplete. Members are requested to advise the Secretary of the name and date of the death of any deceased member not included in this list.

| | |
|---|---|
| McIntyre, John | May 20, 1901. |
| McClure, Robert J. | March 17, 1899. |
| McElroy, Samuel | December 10, 1898. |
| Neu, Peter W. | February 4, 1899. |
| Nourse, Edwin G. | December 8, 1897. |
| Perkins, A. H. | February 24, 1897. |
| Phillips, Jonathan | 1892. |
| Poe, Orlando M. | October 2, 1895. |
| Pope, Willard Smith | October 10, 1895. |
| Porter, J. A. | June , 1885. |
| Reece, Benj. | December 17, 1901. |
| Scherzer, William | July 20, 1893. |
| Schuyler, Howard | December 3, 1883. |
| Smith, Lyman | July 9, 1898. |
| Smith, Warren Collier | March 29, 1895. |
| Talcott, Edward B. | February , 1896. |
| Taylor, William E. | February 4, 1883. |
| Turknett, Robert G. | July , 1889. |
| Watson, Joseph A. | February 5, 1893. |
| Whitney, Nelson O. | March 17, 1901. |
| Whitton, A. D. | February 23, 1892. |
| Wolcott, Alexander | August 11, 1884. |
| Yoder, Wm. J. | September 28, 1901. |

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Journal of the Institution of Electrical Engineers, London, Eng.,

Proceedings of the Institute of Mechanical Engineers, London, Eng.,

Transactions of the American Society of Civil Engineers,

Transactions of the American Society of Mechanical Engineers,

Transactions of the American Institute of Mining Engineers,

Transactions of the American Institute of Electrical Engineers,

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## FOREIGN LIST.

Annales del Institutio de Injenieros de Chili, South America.

Annales des Ponts et Chaussees, Paris.

Archiv fur Eisenbahnwesen, Berlin, Germany.

Association des Ingenieurs, Brussels, Belgium.

Automotor & Horseless Vehicle Journal, London, England.

Automotor Journal, London, Eng.

Bibliographie Des Sciences et de L'Industrie, Paris.

British Association Waterworks Engineers, London.

Boletin di Obras Publicas de la Republica Argentina, Buenos Aires, South America.

Bulletin of the Imperial Technical School, Moscow, Russia.

Bulletin of the International Railway Congress, Brussels. (English Edition.)

Colliery Guardian, London, England.

Conservatoire National des Arts et Metiers, Annales de. Paris, France.

der Praxis des Dampfkessel und Dampfmaschinen Betribes, Berlin, Germany.

## FOREIGN LIST—Continued.

Domestic Engineering, Liverpool, England.
Electrical Engineer, London, England.
Electrical Review, London, England.
Electricity, London, England.
Engineer, The, London, England.
Engineering, London, England.
Engineering Association of N. S. W., Sidney, Australia.
Engineering Times, London.
Feilden's Magazine, London.
Indian Engineering, Calcutta, India.
Institution of Civil Engineers, Proceedings, London, England.
Institution of Junior Engineers, London, England.
Institution of Mechanical Engineers, Transactions of, London, Eng.
Institution of Naval Architects, Transactions of, London, Eng.
Iron & Coal Trade Review, The, London, England.
Iron & Steel Trades Journal, London, England.
Journal of the Institution of Electrical Engineers, London, Eng.
Journal of the Society of Arts, London, England.
Journal of the Society of Mechanical Engineers, Tokyo, Japan.
Konigliche Mechanisch - Techniche Versuch, Ansalten, Charlottenburg, Berlin, Germany.
Koninklyk Inst. Van Ingenieurs, s'Gravenhage, Netherlands.
Liverpool Engineering Society, Liverpool, England.
Locomotive Magazine, London, England.
Manchester Literary & Philosophical Society, Proceedings of, Manchester, England.
Mechanical Engineer, The, London, England.
Mechanical World, Manchester, England.
Mining Journal, London, England.
Model Engineer & Amateur Electrician, The, London, England.
N. E. Coast Institute of Engineers & Shipbuilders, New Castle-on-Tyne, England.
North of England Institute of Mining & Mechanical Engineers, New Castle-on-Tyne, England.
Philosophical Society of Glasgow.
Plumber & Decorator, London, England.
Polytechnic Monthly Journal of Japan.
Practical Engineer, Manchester, England.
Public Health Engineer, London, England.
Railway Engineer, The, London, England.
Revue Practique de L'Electricity, Paris, France.
Revue Technique, Paris, France.
Royal Engineers Institute, Chatham, England.
Royal Scottish Society of Arts, Edinburgh, Scotland.
Science Abstracts, London, England.
Societe des Ingenieurs Civils de France, Annals de Paris France.
Societe Industrielle de Muhlhouse, Buletin of, Muhlhouse, Alsace, Germany.
Societe Internationale des Electriciens, Bulletin de la, Paris, France.
Society of Engineers, London.
Teknisk Tidskrift, Stockholm, Sweden.
Thonindustrie-Zeitung, Berlin, Germany.
Trade Journals' Review, Manchester, England.
Water Supply Dept., Reports of, Brisbane, Australia.
West of Scotland Iron & Steel Institute, Glasgow.
Zeitschrift der Centralverband des Dampfkessel Ueberwachungs Verein, Berlin, Germany.
Zeitschrift des Vereines Deutscher Ingenieure, Berlin, Germany.

## DOMESTIC LIST.

Academy of Natural Sciences, Philadelphia, Pa.
Age of Steel, St. Louis, Mo.
American Architect & Building News, Boston, Mass.
Amer. Assen. Municipal Improvements, Allegheny, Pa.
American Contractor, Chicago.
American Electrician, New York City.
American Engineer & Railroad Journal, New York City.
American Geographical Society, Bulletin of, New York City.
American Institute of Architects, Quarterly, Washington, D. C.
American Institute of Electrical Engineers, New York City.
American Institute of Mining Engineers, New York City.
American Journal of Science, New Haven, Conn.
American Lumberman, Chicago.
American Machinist, New York City.
American Miller, Chicago.
American Philosophical Society, Philadelphia, Pa.
American Society of Civil Engineers, Transactions of, New York City.

DOMESTIC LIST—CONTINUED.

American Society of Heating and Ventilating Engineers. Transactions of, New York City.
American Society of Mechanical Engineers, New York.
American Society of Naval Engineers, Journal of, Washington, D. C.
American Telephone Journal, New York.
American Water Works Association, New York.
Annals American Academy Political and Social Science, Philadelphia, Pa.
Architects' & Builders' Magazine, New York.
Association of Civil Engineers, Transactions of, Ithaca, New York.
Association of Engineering Societies, Journal of, Philadelphia, Pa.
Association of Ontario Land Surveyors, Toronto, Canada.
Automobile & Motor Review, New York.
Black Diamond, Chicago.
Board of Trade, Reports, Chicago.
Boiler Maker & Sheet Metal Worker, Chicago.
Boston Journal of Commerce & Textile Industries, Boston, Mass.
Brick, Chicago.
Brooklyn (N. Y.) Engineers' Club, Proceedings of.
Bureau of Health, Denver.
Canadian Engineer, Toronto and Montreal, Canada.
Canadian Mining Inst., Montreal, Que.
Canadian Mining Review, Ottawa.
Canadian Society of Civil Engineers, Montreal, Que.
Cassier's Magazine, New York City.
Cement, New York.
Cement & Engineering News, Chicago.
Cement & Slate, Allentown, Pa.
Central Railway Club, New York City.
Clay Worker, Indianapolis, Ind.
Colorado Scientific Society, Denver, Colo.
Colorado State Board of Health, Reports, Denver, Colo.
Colorado State Engineer, Denver.
Commerce & Finance of U. S., Washington, D. C.
Compressed Air, New York City.
Connecticut Society of Civil Enginers, New Haven.
Construction News, Chicago.
Cordage Trades Journal, New York City.
Electrical Review, New York City.
Electrical World & Engineer, New York City.
Electricity, New York City.
Engineering Association of the South, Proceedings of, Nashville, Tenn.
Engineering & Mining Journal, New York City.
Engineer, The, Cleveland, O.
Engineering Magazine, New York.
Engineering News, New York City.
Engineering Record, New York City.
Engineering Review, New York.
Engineering Society, School of Practical Science, Toronto, Canada.
Engineers' Club, Philadelphia.
Engineers' Club, St. Louis, Mo.
Engineers' Society of Western New York, Buffalo, N. Y.
Engrs. Society of Western Penna., Pittsburg.
Forestry & Irrigation, Wash. D. C.
Foundry, Cleveland.
Franklin Institute, Journal of, Philadelphia, Pa.
Ice & Refrigeration, Chicago.
Ill. State Geologist.
Illinois Society of Engineers and Surveyors, Peoria, Ill., Reports of.
Indiana Eng'r Society, Indianapolis.
Indiana State Geologist, Indianapolis.
Inland Architect, Chicago.
Insurance Engineering, New York.
Iowa Engineer, The, Ames, Iowa.
Iowa Engineering Society, Cedar Rapids.
Iron Age, New York City.
Iron & Steel, Chicago.
Iron Trade Review, Cleveland, Ohio.
Irrigation Age, Chicago.
Journal of the Military Service Institution, Governor's Island, New York.
Kansas University Quarterly, Lawrence, Kansas.
League of American Municipalities, Proceedings of, Des Moines, Iowa.
Lippencott's Monthly, Philadelphia.
Literary Digest, New York.
Locomotive, The, Hartford, Conn.
Lumber Review, Chicago.
Maine State Bd. of Health, Augusta, Me.
Manchester Institute of Arts & Sciences, Manchester, N. H.
Manufacturers' Record, Baltimore, Md.
Marine Engineering, New York City.
Marine Review, Cleveland, Ohio.
Massachusetts Institute of Technology, Catalogue, Boston, Mass.
Master Car Builders' Association, Chicago.
Metal Worker, New York City.
Michigan Agricultural College, Reports of, Agricultural P. O., Ingham Co., Mich.
Michigan Engineering Society, Climax, Mich.
Michigan Mining School, Catalogue, Houghton, Mich.
Michigan State Board of Health, Lansing, Mich.
Mines and Minerals, Scranton, Pa.

### DOMESTIC LIST—CONTINUED.

Mining Reporter, Denver, Colo.
Mining Review, Ottawa, Canada.
Mining & Scientific Press, San Francisco, Cal.
Modern Machinery, Chicago.
Monist, The, Chicago.
Montana Society of Engineers, Butte, Montana.
Monthly Official Railway List, Chicago.
Municipal Engineering, Indianapolis, Ind.
National Builder, Chicago.
National Engineer, Chicago.
National Homemaker, Washington, D. C.
New England Cotton Manufacturers' Association, Boston, Mass.
New England Railway Club, Springfield, Mass.
New England Water Works Association, Journal of, Boston, Mass.
New Hampshire Agricultural College, Reports of, Durham, N. H.
New Hampshire State Bd. of Health.
New York Railroad Club, Brooklyn, N. Y.
New York State Board of Health, Albany, N. Y.
North-West Railway Club, St. Paul, Minn.
Nova Scotia Institute of Science, Halifax, Nova Scotia.
Official Guide of the Railway and Steam Navigation Lines, New York.
Ohio Sanitary Bulletin, Columbus, O.
Ohio State Board of Health.
Ohio Society Surveyors and Civil Engineers, Reports of, Columbus, O.
Open Court, The, Chicago.
Patent Office Weekly Gazette, Department of the Interior, Washington, D. C.
Pacific Coast Railway Club, Proceedings, Sacramento, Cal.
Physical Review, Cornell University, Ithaca, N. Y.
Power, New York City .
Power and Transmission, Mishawaka, Ind.
Pratt Institute Monthly, Brooklyn, N. Y.
Proceedings Board of Trustees Sanitary District, Chicago.
Proceedings United States Naval Institute, Washington, D. C.
Progressive Age, New York City.
Public Opinion, New York City.
Queen's Quarterly, Kingston, Ontario.
Railroad Gazette, New York City.
Railroad Car Journal, New York City.
Railroad Men, New York City.
Railway & Locomotive Engineering New York.
Railway Age, Chicago.
Railway Machinery, New York City.
Railway Master Mechanic, Chicago.
Railway & Engineering Review, Chicago.
Rensselaer Polytechnic Institute, Catalogue, Troy, N. Y.
Roadmaster & Foreman, Chicago.
Road Master & M. of W. Assen., Reports, Sterling, Ill.
Rose Polytechnic Institute, Catalogue, Terre Haute, Ind.
Scientific American, New York City.
Sibley Journal Mechanical Engineering Ithaca, N. Y.
Smithsonian Institution, Washington, D. C.
Statistics, City of Chicago.
Steam Engineering, Chicago.
Stevens Indicator, Hoboken, New Jersey.
Stone, New York City.
Street Railway Journal, New York City.
Street Railway Review, Chicago.
The Technograph, University of Illinois, Urbana, Ill.
Technology Review, The, Boston, Mass.
Telephone Magazine, Chicago.
Tin & Terne, Pittsburg, Pa.
The Tradesman, Chattanooga, Tenn.
United States Artillery Journal, Fortress Monroe, Va.
U. S. Naval Institute, Annapolis, Md.
U. S. Weather Bureau.
Water & Gas Review, New York City.
Western Electrician, Chicago.
Western Railway Club, Chicago.

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